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Ankle Kinetics During Landing Tasks in Participants with Chronic Ankle Instability and Uninjured Controls

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ANKLE KINETICS DURING LANDING TASKS IN PARTICIPANTS WITH CHRONIC ANKLE INSTABILITY AND UNINJURED CONTROLS

by

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(Under the Direction of Barry Munkasy)

ABSTRACT

Lateral ankle sprains are a common injury sustained by physically active individuals. Many of these individuals will incur repetitive episodes of lateral ankle sprain, resulting in chronic ankle instability (CAI). CAI has been heavily researched, but few conclusions have been drawn. Much of this research has focused on sagittal plane kinematics and kinetics. Therefore, the purpose of this study was to compare three-dimensional ankle joint kinetics during functional landing tasks in participants with CAI and uninjured controls. Participants performed single-leg vertical drop landings and single-leg cross-over landings. There were no significant differences between the two groups for ankle net joint moments (plantarflexion/dorsiflexion, inversion/eversion, internal/external rotation) and ankle net joint forces (axial, anterior/posterior, medial/lateral) at any time point from ground contact to 150 ms after. We conclude that those with CAI do not suffer from an alteration in motor programming, and are able to absorb forces upon landing similar to uninjured individuals.

INDEX WORDS: Ankle instability, Landing, Kinetics

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by

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DEDICATION

I dedicate this to my parents who have shown tremendous love and support throughout the process of completing my thesis. Without them none of this would have been possible.

ACKNOWLEDGMENTS

Special thanks to Bryan Riemann for being an extraordinary mentor throughout the last two years. Thank you for all of your guidance, humor, and knowledge in completing this project. Also, for the challenging course work that has allowed me to become a more well-rounded, competent athletic trainer. What I have learned from you, not only about the athletic training profession, but life as well is invaluable. Thank you!

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CHAPTER 1

INTRODUCTION

Ankle sprains are the most common injury sustained by the active population. Nearly 80% of those individuals who incur an ankle sprain have a recurrent episode.[1-3] Many of these injuries occur during some type of landing activity, prevalent in most every athletic activity.[4, 5] Ultimately, the consequences of these recurrent episodes can lead to chronic ankle instability (CAI), which is specifically defined as the occurrence of repetitive bouts of lateral ankle instability that result in numerous sprains.[6] Due to the high incidence of CAI, researchers have focused on many possible etiologies that could be responsible for this problem. This research has produced contradictory results, leaving understanding in a state of uncertainty.

Traditionally, researchers have hypothesized that CAI is a result of such factors as decreased strength of the musculature surrounding the ankle[7-9], decreased peroneal reaction time[10-12], and/or a decreased ability to detect joint position/motion.[8, 13] Common to these early reports, measurements were made in isolated testing conditions, whereas ankle sprains occur during functional activities. More recently, focus has shifted to examining kinematics and ground reaction forces during functional activities such as walking[14, 15] and landing[16, 17]. Because landing is a frequent task imbedded within sports-related activity, examining landing strategies in CAI patients appears to have immediate relevance. Ankle injuries occur more frequently during landing tasks than any other functional activity.[5] Landing is a complex activity that requires a coordinated movement of the entire body to dissipate forces safely. Reflex activity to produce a recovery movement upon weight bearing is too slow,[11, 18] suggesting that a more critical aspect in landing properly is preprogrammed motor patterns. It is hypothesized that when one sustains an ankle sprain, an alteration may occur in this preprogrammed pattern. Unfortunately, the two studies found that investigate CAI landing strategies only considered vertical jump landings and sagittal plane measurements.[16, 17] Common to many functional activities are multiplanar movements that may induce high levels of shear forces and moments about the ankle joint. Furthermore, to date, no investigation was found that has considered ankle joint kinetics in patients with CAI. A three dimensional ankle joint kinetic analysis, by providing estimates of the moments and forces (axial, shear) across the ankle joint complex, may better reveal factors that contribute to CAI.

An additional factor that confounds the CAI literature is the wide range of operational CAI definitions and participant activity levels. To assist in drawing consensus, there is a need to more thoroughly describe study participants in research examining CAI. Two scoring scales have been developed with the purpose of establishing the degree of residual ankle impairments[19] and functional level[20], however to date they have not been used in conjunction with biomechanical studies. Use of these scales may establish a more objective measurement of the CAI participants. Quantifying instability level will help with generalizing results to people with similar levels of CAI.

The purpose of this study was to compare ankle joint kinetics in those with CAI and uninjured controls during multiplanar landing activities that mimic various components of sport-related activity. It was hypothesized that those with CAI would sustain significantly different plantarflexion/dorsiflexion (PF/DF), inversion/eversion (IV/EV), and internal/external rotation (IR/ER) net joint moments (NJM) upon impact compared to the uninjured control group during the vertical landing task. It has been reported in previous research by Cauffield at al.[16, 21] that those with CAI have differences in landing kinematics and muscle activation compared to uninjured participants during a vertical drop landing. Because of these reported differences in biomechanical variables, we hypothesized that the participants in our study would experience differences in NJMs because of alterations in joint position upon landing.

The CAI group was also hypothesized to experience significantly different axial and shear (anterior/posterior (AP), medial/lateral (ML)) net joint forces (NJF) than the uninjured control group during the vertical drop landing. While, there were no studies found that measured kinetics in CAI and uninjured groups upon vertical drop landing, there have been differences reported in ground reaction force. In a study by Cauffield et al.[17], those with CAI sustained higher ground reaction forces earlier upon landing than an uninjured group. It has also been reported that lower extremity kinematics during a vertical drop landing affect the ground reaction forces upon landing[22].

For the cross over landing task, we hypothesized that a significant difference would exist between the CAI and uninjured control groups in the PF/DF, IV/EV, and IR/ER NJM. There were no studies found which utilized a cross over landing task in CAI and uninjured control groups. Monaghan et al.[23] reported differences in inversion NJM between CAI and uninjured groups upon heel strike during gait. While this difference was reported during a uniplanar activity, we expected further differences to occur during a multiplanar landing.

We also hypothesized there would be a significant difference between the CAI and uninjured control group in axial and shear (AP, ML) NJF during the cross over landing task. Cross over landing has been speculated to create more rotational forces. Due to deficits in lateral ankle support which characterize, CAI, we hypothesized that those with CAI would experience different NJF upon cross over landing due to the challenge of dissipating rotational forces. When one sustains injury, an alteration in the centralized motor program may occur to compensate for the feelings of instability[16, 17]. A difference in the motor program may affect the way a task is carried out, and the dissipation of landing forces, thus resulting in a difference in the NJM and NJF.

CHAPTER 2

METHODS

Participants

Thirty-six college aged (18 - 25 yrs) participants (28 males, 8 females) volunteered for this study: 18 with CAI (height = 178.58 ± 11.99 cm, mass = 88.88 ± 15.27 kg), and 18 uninjured matched controls (height = 180.62 ± 10.95 cm, mass = 83.22 ± 14.17 kg). All participants were recruited from a physically active population, and were involved in physical activity classes and/or athletic practices. Physically active was defined as participating in physical activity at least three days a week for 20 minutes in duration, and a score of five or better on the Tegner and Lysholm[24] activity level questionnaire. All CAI participants (experimental group) met the following criteria: 1) A moderate to severe initial sprain that required medical attention; 2) Experienced at least two moderate ankle sprains (required medical attention) to the same ankle no more than 12 months ago, but greater than one month before this study; 3) Experienced weakness and/or pain from this sprain before, but completely asymptomatic at the time of study.

The uninjured controls were matched to the CAI group according to sex, height (± 5.08 cm), mass (± 4.55 kg), activity type/level, and test limb (the same limb used by the matched counterpart, right or left). The uninjured control group had no previous history of injury or surgery to either ankle joint. All participants were screened through the use of a medical history (Appendix D) and activity level questionnaires[24] (Appendix E), as well as the Ankle Activity Score[19] (Appendix F). The Ankle Activity Score (AAS) consists of a subjective evaluation of ankle instability as well as measures of strength, range of motion, and functional ability for the purpose of quantifying the degree of ankle instability. Participants in both groups were excluded from participation if they had previously suffered from any orthopedic injury to the spine or lower extremity in the past six months and/or were currently injured. Suffering from any neurological, vestibular, or balance disorders also excluded participants from the study.

Procedures

This study utilized a comparison group repeated measures design. Before testing began, informed consent approved by the University Institutional Review Board was obtained. The participants performed two different landing tasks utilizing vertical and anterior/lateral movement. During the testing session, data concerning activity level, degree of instability, as well as participant demographics were collected. Participants were given an overview of the test procedures and a video demonstration of the landing tasks. Instruction on the characteristics of a successful and failed trial was given. They were then allowed to practice each task five times under the supervision of the principal investigator. Once the participant understood the tasks, actual testing began. Electromagnetic sensors were secured to the skin over the midfoot, tibia, and thigh using double-sided tape and self-adhering tape. The participant landed onto a forceplate barefoot.

Single Leg Vertical Landing: The participant stood on a platform in front of a force plate at a vertical height equal to 20% of body height. The platform was placed 10 cm from the front of the forceplate. All weight was rested on the contralateral limb, while the test limb was relaxed. The contralateral limb was used to propel the participant off the platform to land on the test limb in the middle of the force plate (As defined by

Cauffield et al[16, 17]). The participant placed his/her hands on hips, and was instructed to drop off the platform without jumping up or lowering the body closer to the forceplate.

Cross-over Single Leg Hop: The participant performed a modified cross-over single leg hop. The hop was performed in an anterior-lateral direction at a 45 degree angle. The target distance was calculated as 45% of the participant's height (± 5%)[25]. The hands were placed on the hips throughout the task.

A trial was considered successful if executed without any errors according to the error-scoring system (Table 1). If an error occurred, that trial was discarded and redone. Each participant performed five successful trials for each task.

Table 1 Error-Scoring System (adapted from Riemann et al.[25])

Landing errors	Not covering tape mark
	Stumbling on landing
	Hands off hips
	Not sticking the landing (i.e. no extra hops or repositioning of foot once the participant has contacted the forceplate)
	Not holding landing for at least 3 seconds
	Touching down with non-test limb before test is completed

Instrumentation

A mid-range electromagnetic tracking system (miniBird, Ascension Technology, Burlington, VT) was used to collect three-dimensional kinematic data at a sampling frequency of 100 Hz. Because the sensors are smaller in size and mass, the miniBird system was used to provide more precise kinematic and kinetic data regarding the foot and tibia. One sensor was placed on the forefoot, one on the medial tibia, and one on the lateral lower thigh. Motion Monitor (Innovative Sports Training, Chicago, IL) software was used to calculate sensor position and orientation with respect to a global reference system. Custom software (MATLAB) was used to translate the sensor axes into a segmental reference system so anatomically appropriate calculations could be made with respect to the ankle according to the International Society for Biomechanics Ankle Group. Force data were collected using a non-conducting AMTI force plate (AMTI, Watertown, Ma). The force plate data were upsampled and synchronized with the electromagnetic tracking system at 1000 Hz.

Data Reduction

All data reductions were conducted using MATLAB based software. The period of interest began when the vertical ground reaction force exceeded 5% of body mass and concluded 150 ms later.[16, 17] Kinetic analyses included shear (AP, ML) and axial NJF and PF/DF, IV/EV, and IR/ER NJM about the ankle complex. NJF and NJM were computed using standard biomechanical practices[26].

Statistical Analysis

For each task (vertical and cross-over), ensemble means and standard deviations at each time point of interest were calculated for each dependent variable (3 levels for NJM and 3 levels for the NJF). The 95% confidence intervals for the differences between the CAI and uninjured control group were calculated using independent t-tests. Statistical significance was considered at $P<.05$. Differences between the groups were taken to be statistically significant if the confidence intervals did not contain zero.

CHAPTER 3

RESULTS

A total of 36 participants completed both landing tasks for this study, 18 with CAI and 18 uninjured matched controls. For the vertical landing task, no significant differences were found between the groups for all levels of NJM ($P>.05$) (PF/DF, IV/EV, IR/ER). There were also no significant differences found for the 3 levels of NJF ($P>.05$) (axial, AP, ML). For the cross-over landing task, similar results were found, with no significant differences between the groups for the NJMs and the NJF ($P>.05$).

Vertical Landing Task

Participants in both groups landed with a PF NJM (Figure 1) at ground contact that increased in magnitude until reaching a peak around 100 ms after contact. The CAI and uninjured control groups showed a similar pattern for ankle PF NJM at ground contact and throughout the period of interest (0 – 150 ms).

The difference and 95% confidence interval between the mean PF NJM for the CAI and uninjured control groups are given in Figure 2. The 95% confidence interval contains zero, so we conclude that there were no significant differences in the PF NJM between the groups at any time point during the initial 150 ms post ground contact.

Upon landing, participants in the uninjured control group landed and maintained an IV NJM throughout the period of interest, whereas, those in the CAI group displayed an initial EV NJM followed by an IV NJM (Figure 3). Despite these initial differences, the mean difference at all time points between the groups for the IV/EV NJM were not significant ($P>.05$) (Figure 4).

The rotational NJM's were variable within both participant groups, especially those in the CAI group beginning 50 ms following ground contact (Figure 5). On average, those in the uninjured control group landed with an ER NJM throughout the 150 ms. The CAI group also showed a similar ER NJM.

The difference between the mean rotation NJM for the CAI and uninjured control group is given in Figure 6. The 95% confidence interval contains zero, so we conclude that there are no significant differences in the ankle rotation NJM between the groups at any time point throughout 150 ms post ground contact ($P>.05$).

As participants landed during the vertical landing task, they sustained a downward axial NJF that increased in magnitude until reaching a peak around 50 ms post ground contact (Figure 7). Both groups showed very similar amounts of axial NJF starting at ground contact and lasting throughout the 150 ms time period.

The mean difference in axial NJF between the 2 groups is shown in Figure 8. Because the 95% confidence interval surrounds zero, we conclude there are no significant differences between the CAI and uninjured control groups for ankle axial NJF at any time point ($P>.05$).

At ground contact, the uninjured control group shows an initial spike in anterior NJF that peaks around 20 ms before experiencing a larger anterior NJF that peaks around 125 ms. A similar pattern is seen for the CAI group for anterior NJF initially and throughout the remainder of the time period (Figure 9).

Figure 10 displays the mean difference between the groups for ankle AP NJF. We conclude there are no significant differences between the group means at any time point, as our 95% confidence interval contains zero ($P>.05$).

Upon landing, the uninjured control group initially experienced a small lateral NJF around 20 ms followed by a peak in the lateral NJF around 50 and 100 ms (Figure 11). Initially, the CAI group experienced a medial NJF around 20 ms. This was followed by a lateral NJF similar to that of the uninjured control group. It is interesting to note, as shown in the figure, the high variability in ML NJF for both groups.

The mean difference between the groups in the ML NJF is shown in Figure 12. The 95% confidence interval surrounds zero, so there are no significant differences between the CAI and uninjured control groups for the ankle ML NJF at any time point beginning at ground contact to 150 ms ($P>.05$).

Cross Over Landing Task

A PF NJM was experienced during the period of 0-150 ms for both the CAI and uninjured control groups (Figure 13). The magnitude of the PF NJM increased until reaching a peak around 30 ms after ground contact for both groups. The CAI group experienced a slightly higher PF NJM throughout the time period. It is interesting to note the high variability in the ankle PF NJM experienced by the CAI group.

The difference between the group means for the PF/DF NJM is low. We conclude that there are no significant differences between the CAI and uninjured control group at any time point of interest as our 95% confidence interval contains zero ($P>.05$) (Figure 14).

From the point of contact, participants in the uninjured control group landed with an ankle IV NJM that increased in magnitude until reaching a peak around 50 ms after ground contact (Figure 15). CAI participants landed with a pattern consistent with their uninjured counterparts experiencing an IV NJM. While the CAI group experienced a similar IV NJM initially, the magnitude began to decrease until reaching a low peak around 50 ms after ground contact, followed by a similar pattern of IV NJM as the uninjured control group. It is interesting to note the large variability in the IV/EV NJM performed by the CAI group.

Despite the slight differences seen, the mean difference between the groups for the ankle IV/EV NJM was not significant (P>.05) (Figure 16). The 95% confidence interval contains zero, so we conclude that the CAI and uninjured control group landed with similar ankle IV/EV NJM at each time point from ground contact to 150 ms post ground contact.

For the uninjured control group, initially an IR NJM is seen that increased in magnitude until reaching a peak around 25 ms after ground contact. This was followed by an ER NJM that reached a peak around 75 ms after ground contact. A similar pattern is seen in the CAI group (Figure 17). The CAI group initially experienced two small peak IR NJM around 15 ms and 50 ms after ground contact. This was followed by an ER NJM that increased in magnitude until reaching a peak between 75 and 100 ms after ground contact. As shown in Figure 17, the high variability in ankle rotation NJM experienced by the CAI group was interesting to note.

There were no significant differences at any time point in the ankle IR/ER NJM between the CAI and uninjured group (P>.05) (Figure 18). The 95% confidence interval contains zero leading us to this conclusion.

Upon landing, both groups experienced a similar downward axial NJF of increasing magnitude. The uninjured control group reached a peak around 50 ms after ground contact, whereas the CAI group peaked around 75 ms after ground contact.

Despite slight differences between the groups, none were significant (P>.05) (Figure 20). Because the 95% confidence interval contained zero, we concluded there are no significant differences in the axial NJF between the CAI and uninjured groups.

The ankle AP NJF was very similar for both groups (Figure 21). Both experienced an anterior NJF of increasing magnitude that peaked between 100 and 125 ms after ground contact.

The difference between the ankle AP NJF at any time point was not significant (P>.05) (Figure 22). The 95% confidence interval contained zero, supporting this conclusion.

Similar to the vertical landing task, the data concerning ankle ML NJF was highly variable in both groups (Figure 23). The uninjured control group experienced an increasing lateral NJF after ground contact that peaked around 125 ms after ground contact. The CAI group also experienced an increasing lateral NJF of varying magnitudes. They reached an initial peak around 25 ms after ground contact, followed by a further increase in lateral NJF that peaked around 125 ms ground contact.

The mean difference between the groups in ankle ML NJF is displayed in Figure 24. The 95% confidence interval contains zero, leading us to conclude there were no significant differences in ankle ML NJF at any time point between the CAI and uninjured control groups (P>.05).

Figure 1. Group ensemble averaged ankle PF/DF NJM (Nm/kg) for the vertical landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = PF NJM; negative value = DF NJM)

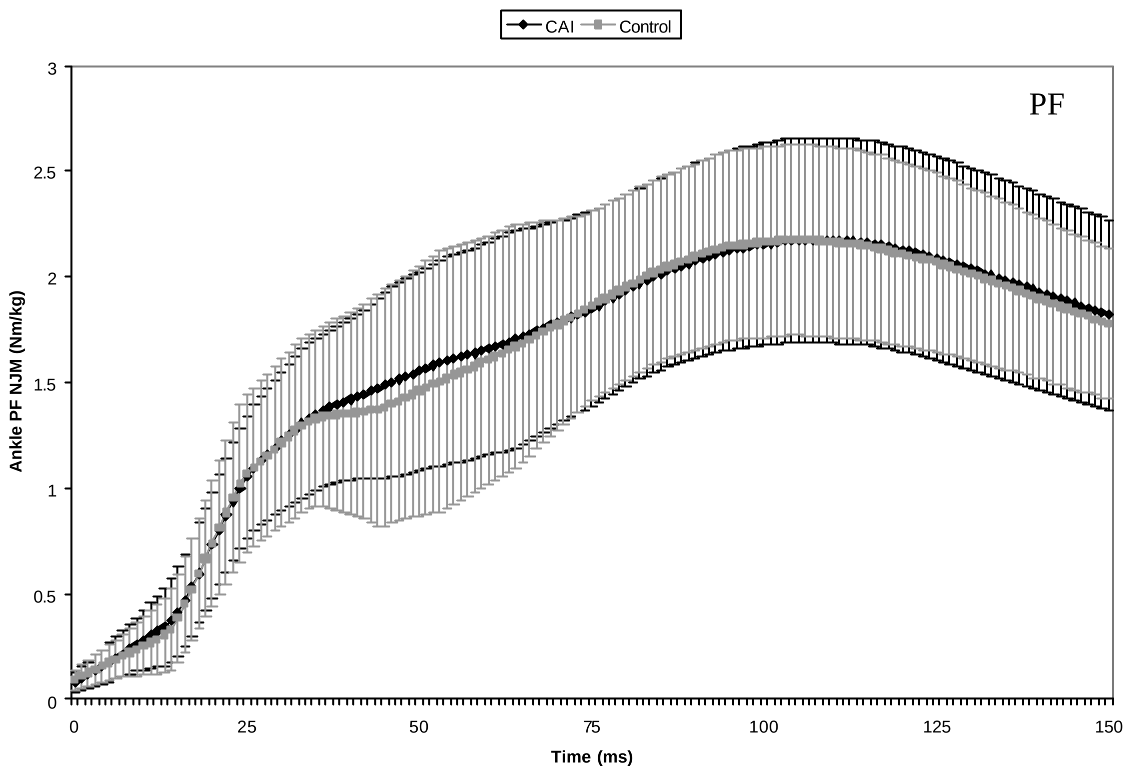


Figure 2. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

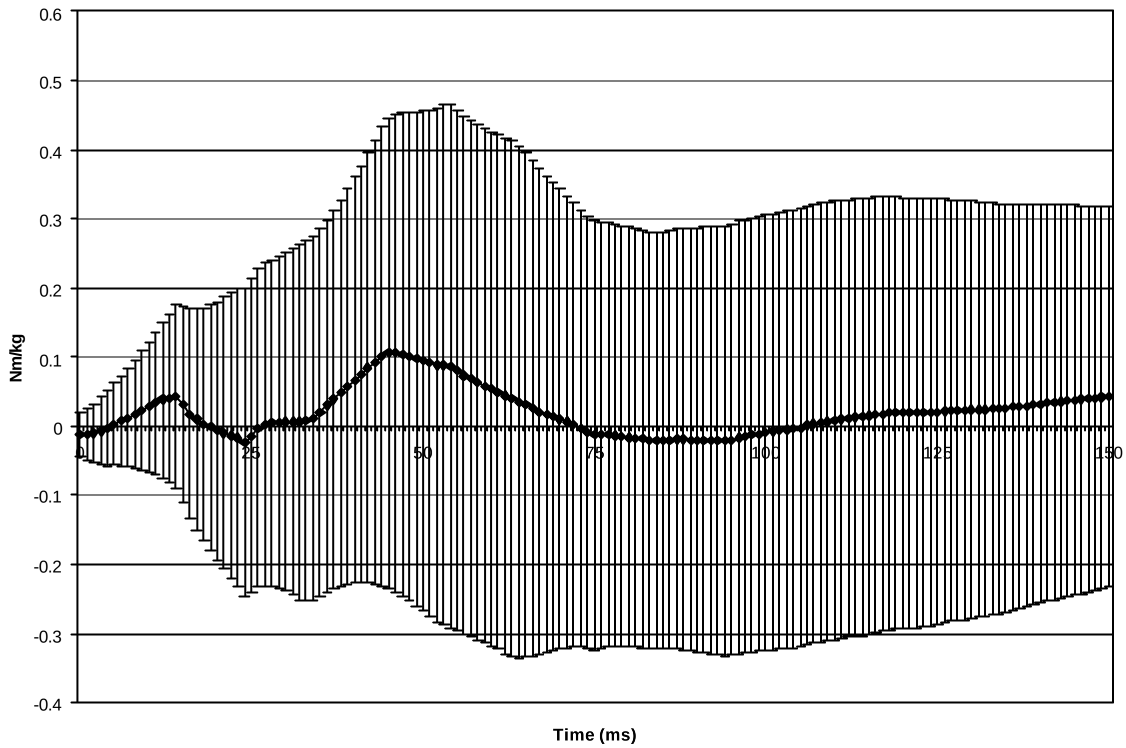


Figure 3. Group ensemble averaged ankle IV/EV NJM (Nm/kg) for the vertical landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = IV NJM; negative value = EV NJM)

Figure 4. Mean difference and 95% confidence interval for ankle IV/EV NJM during the vertical landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

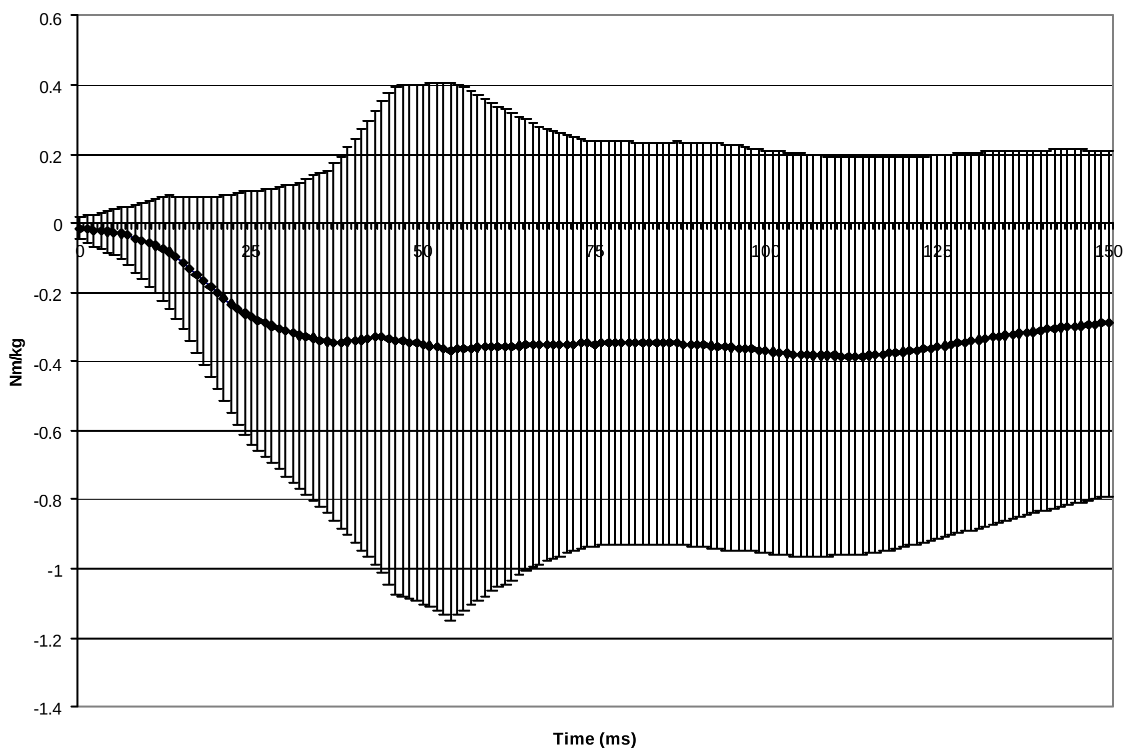


Figure 5. Group ensemble averaged ankle IR/ER NJM (Nm/kg) for the vertical landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = IR NJM; negative value = ER NJM)

Figure 6. Mean difference and 95% confidence interval for ankle IR/ER NJM during the vertical landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

Figure 7. Group ensemble averaged ankle axial NJF (N/kg) for the vertical landing task from ground contact to150 ms after. Error bars represent group standard deviations. (negative value = NJF acting in downward direction)

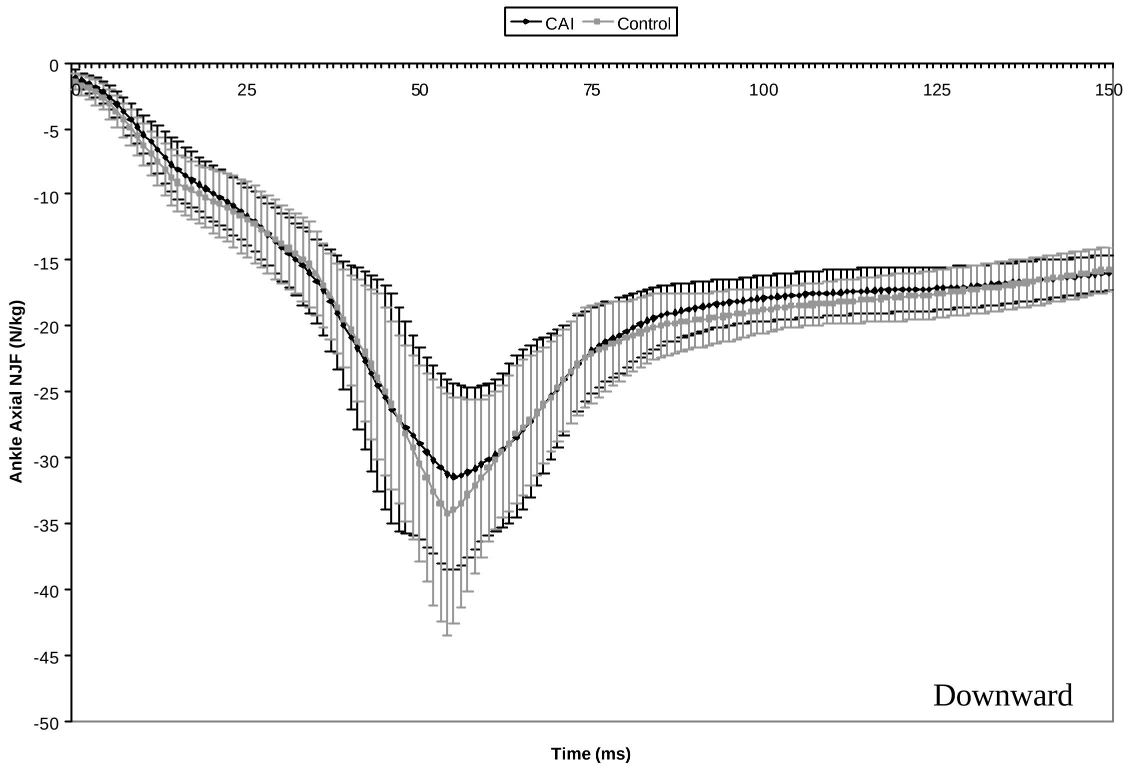


Figure 8. Mean difference and 95% confidence interval for ankle axial NJF during the vertical landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

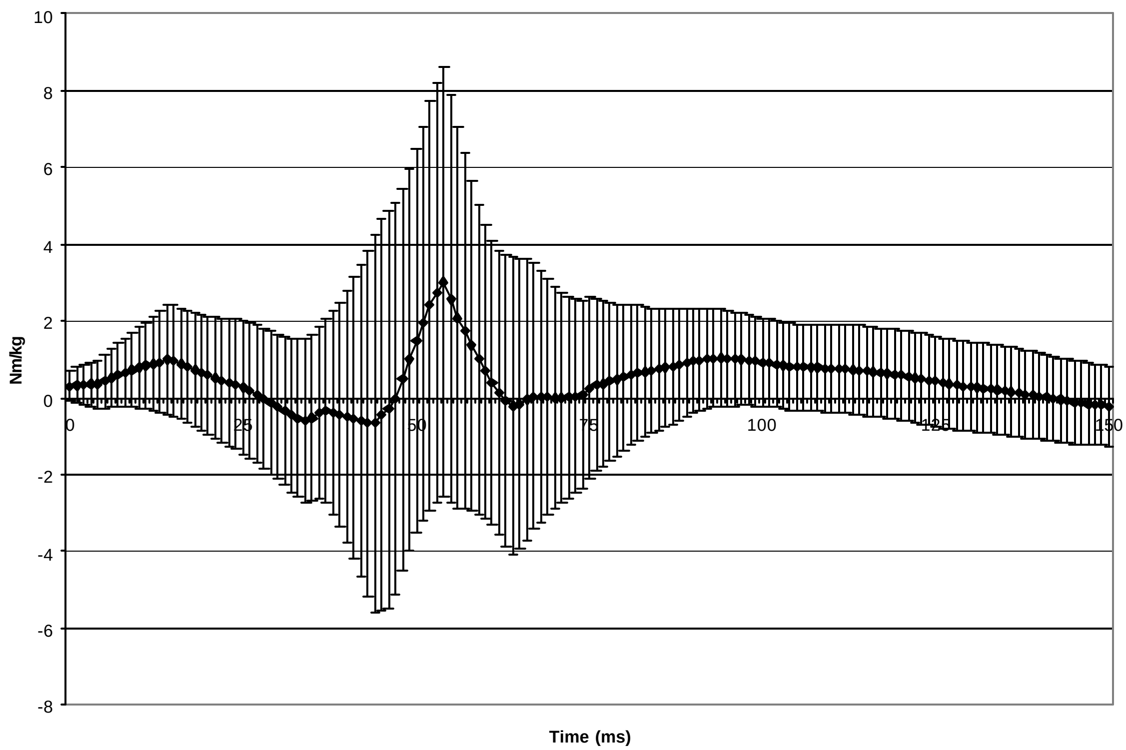


Figure 9. Group ensemble averaged ankle AP NJF (N/kg) for the vertical landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = anterior NJF; negative value = posterior NJF)

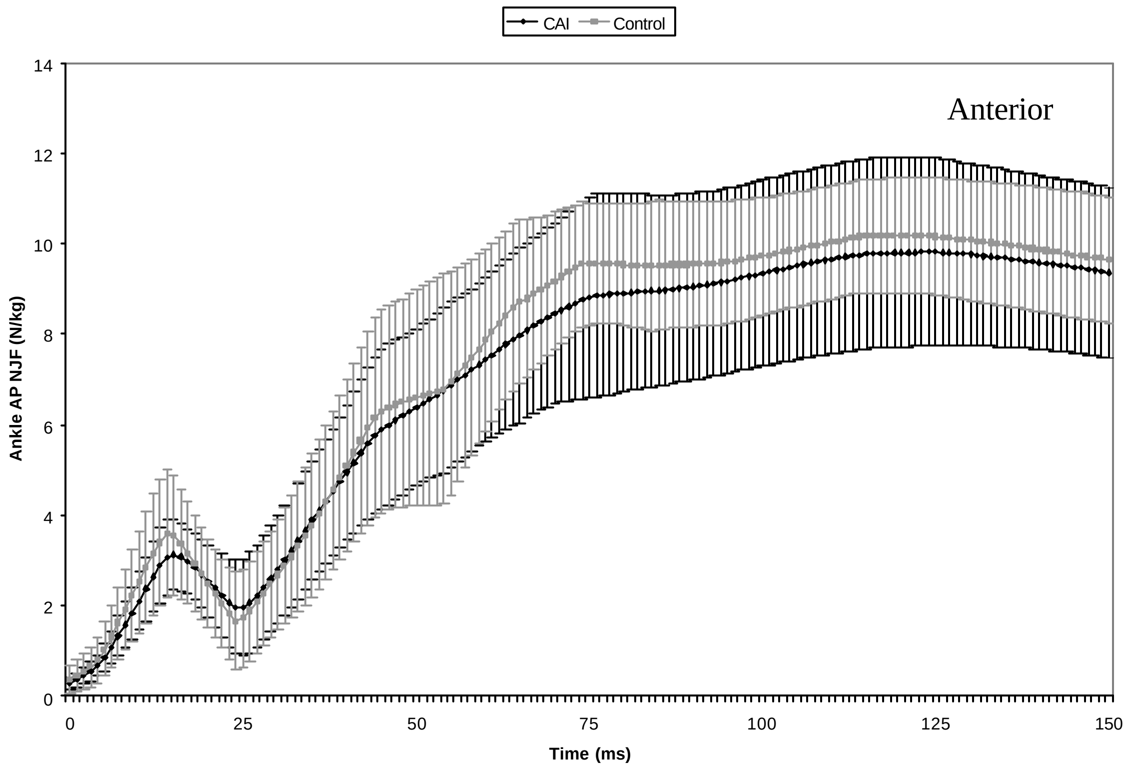


Figure 10. Mean difference and 95% confidence interval for ankle anterior/posterior NJF during the vertical landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

Figure 11. Group ensemble averaged ankle ML NJF (N/kg) for the vertical landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = lateral NJF; negative value = medial NJF)

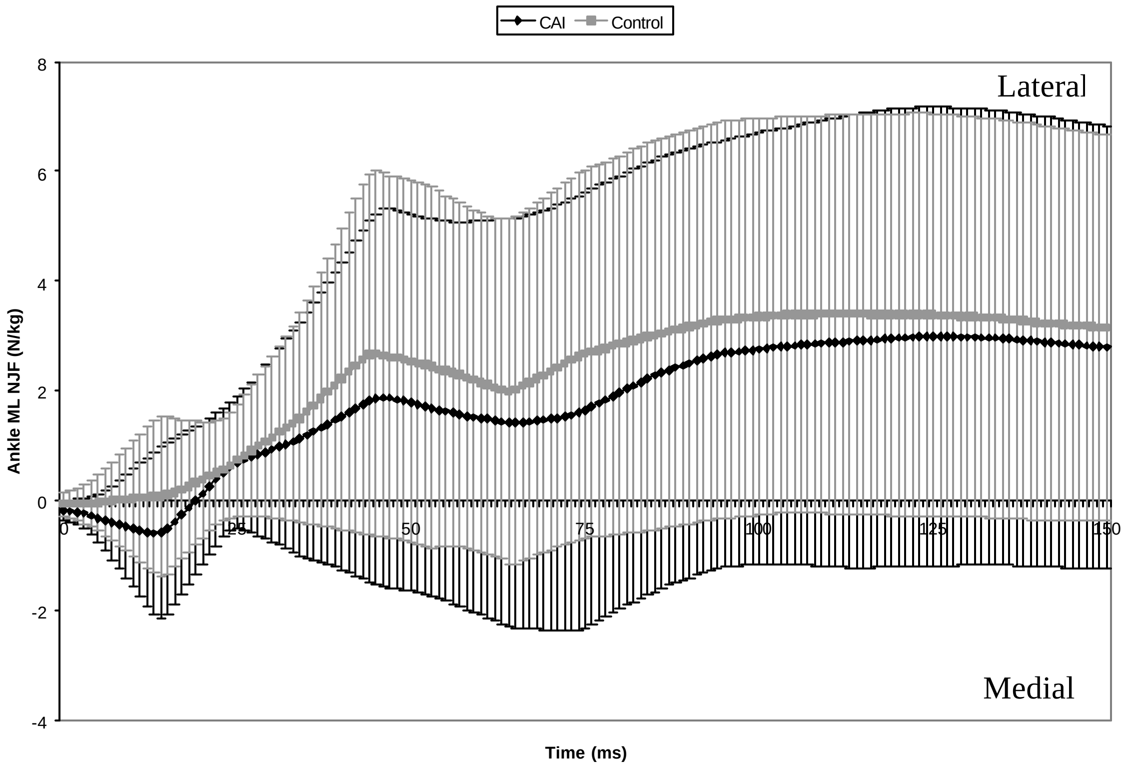


Figure 12. Mean difference and 95% confidence interval for ankle ML NJF during the vertical landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

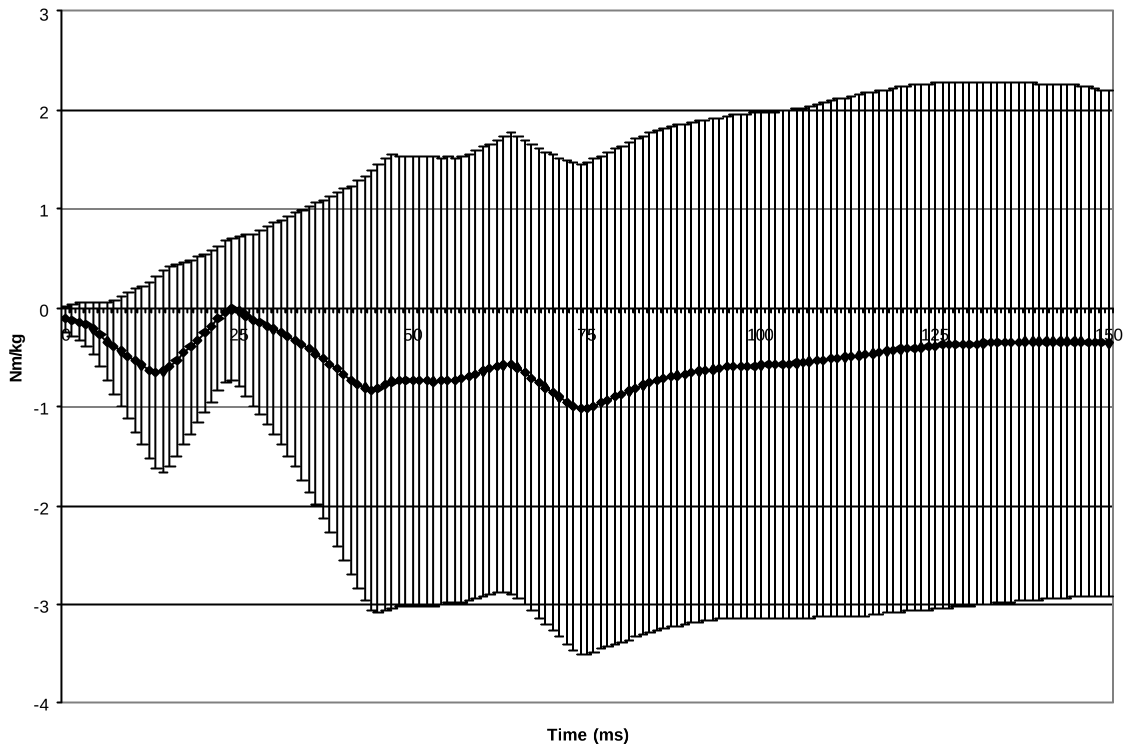


Figure 13. Group ensemble averaged ankle PF/DF NJM (Nm/kg) for the cross over landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = PF NJM; negative value = DF NJM)

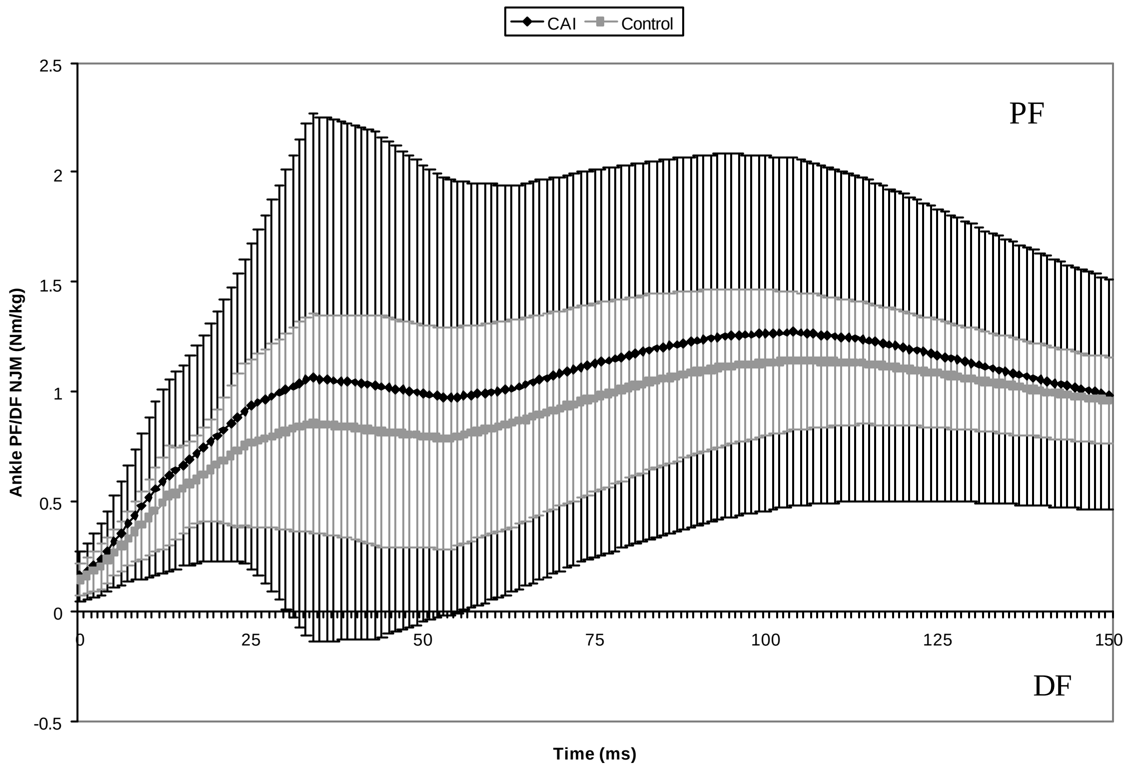


Figure 14. Mean difference and 95% confidence interval for ankle PF/DF NJM for the cross over landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

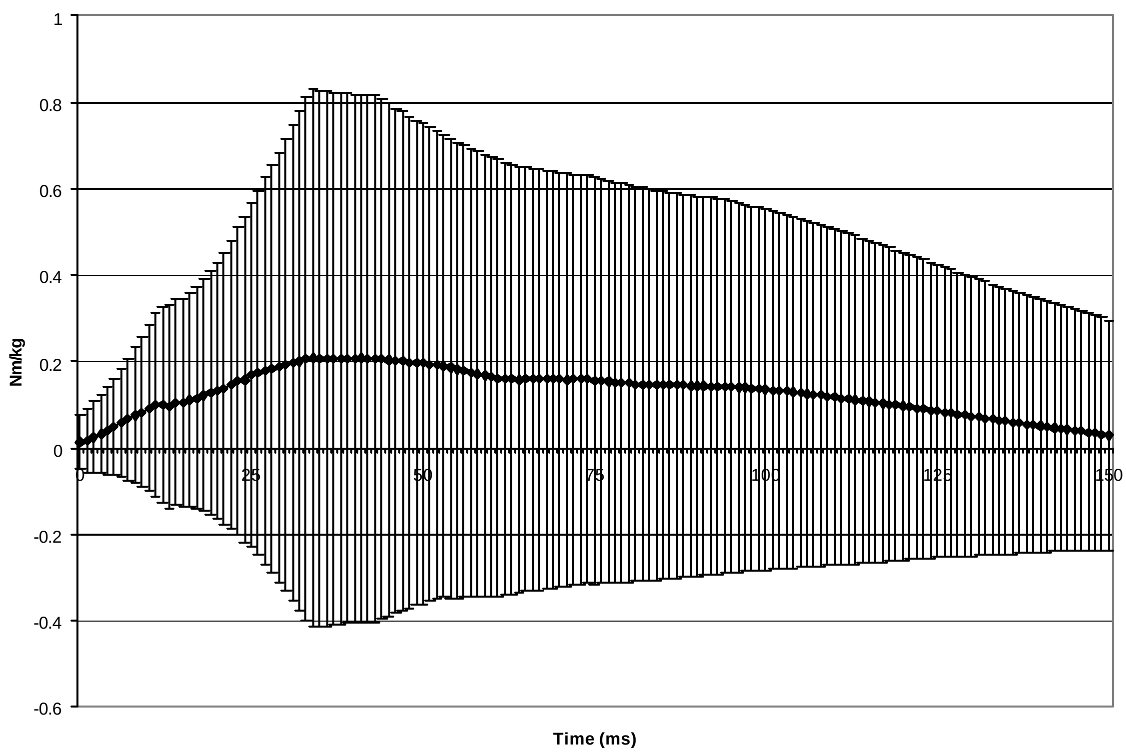


Figure 15. Group ensemble averaged ankle IV/EV NJM (Nm/kg) for the cross over landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = IV NJM; negative value = EV NJM)

Figure 16. Mean difference and 95% confidence interval for ankle IV/EV NJM during the cross over landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

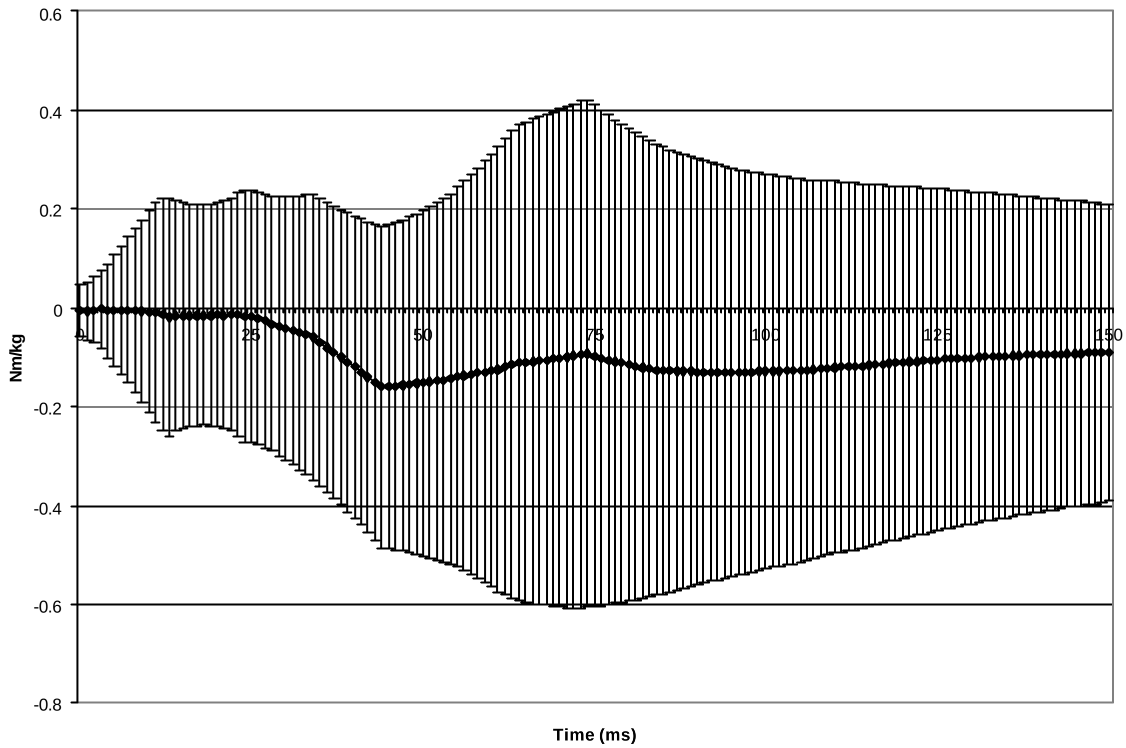


Figure 17. Group ensemble averaged ankle IR/ER NJM (Nm/kg) for the cross over landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = IR NJM; negative value = ER NJM)

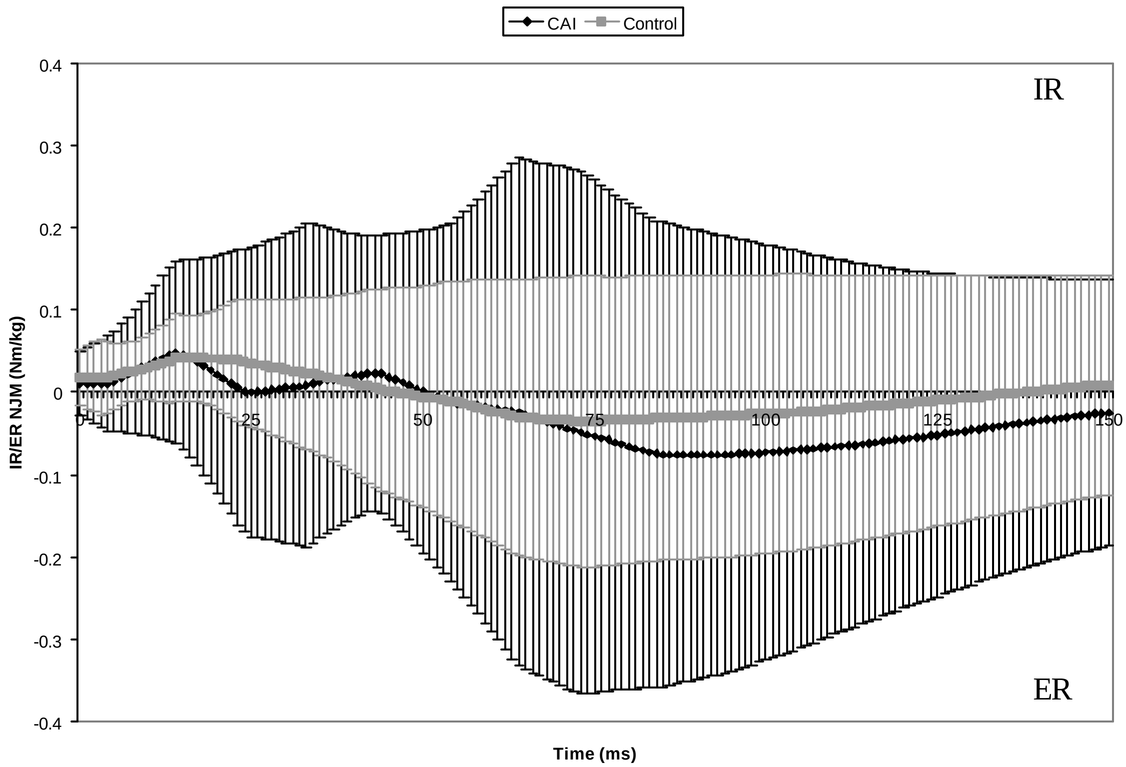


Figure 18. Mean difference and 95% confidence interval for ankle IR/ER NJM during the cross over landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

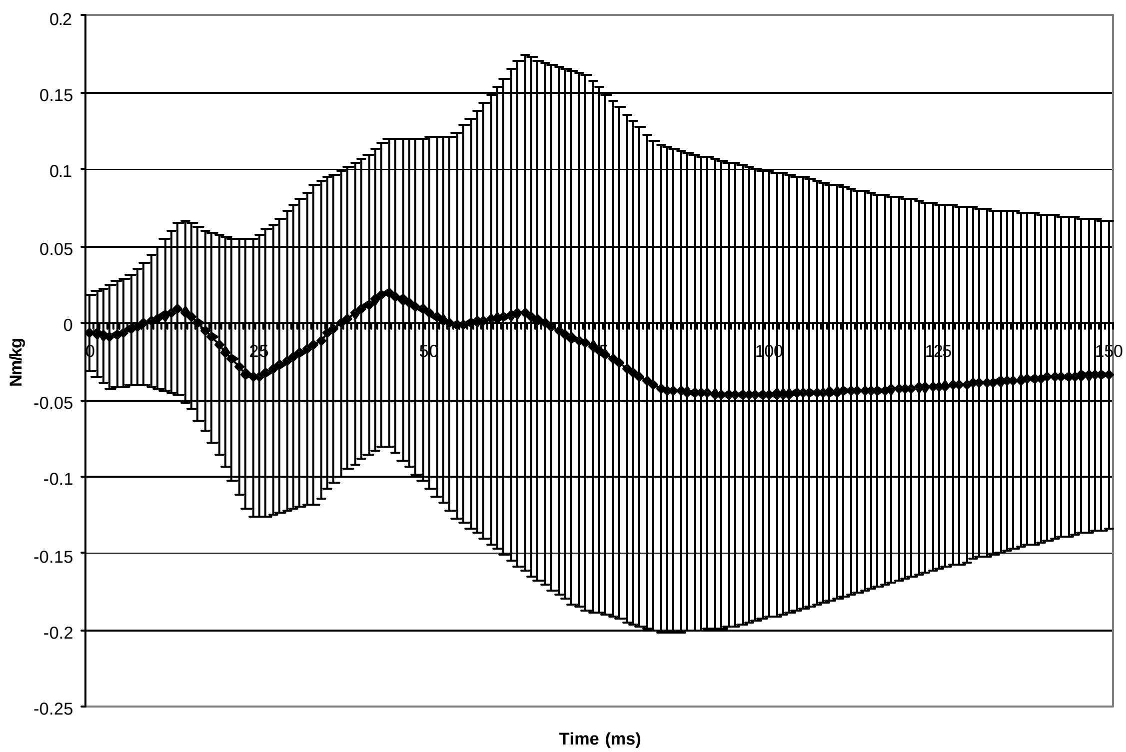


Figure 19. Group ensemble averaged ankle axial NJF (N/kg) for the cross over landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (negative value = NJF acting in downward direction)

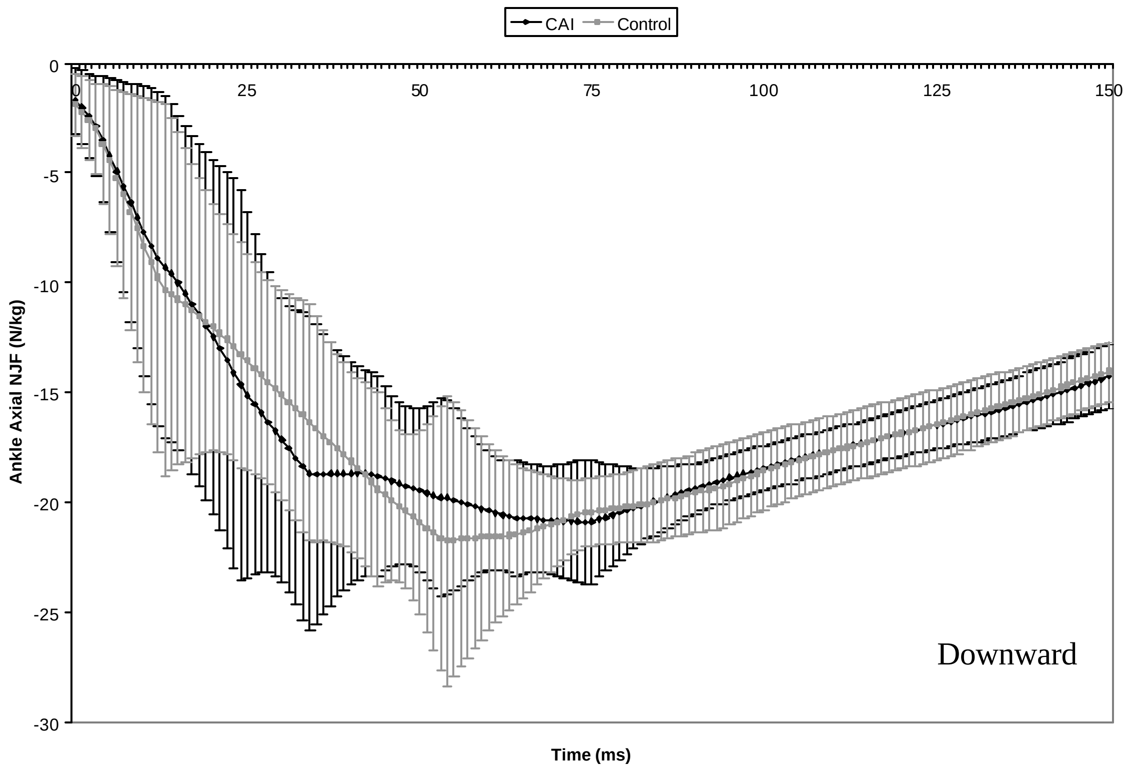


Figure 20. Mean difference and 95% confidence interval for ankle axial NJF during the cross over landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

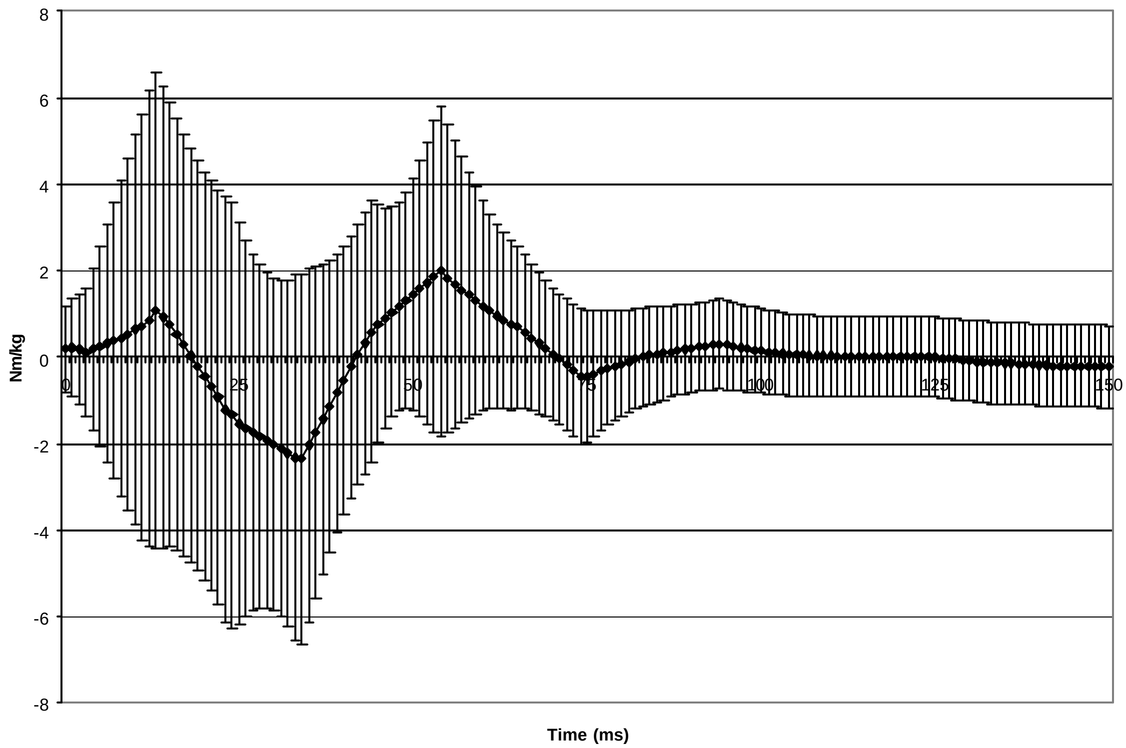


Figure 21. Ensemble averaged ankle AP NJF (N/kg) for the cross over landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = anterior NJF; negative value = posterior NJF)

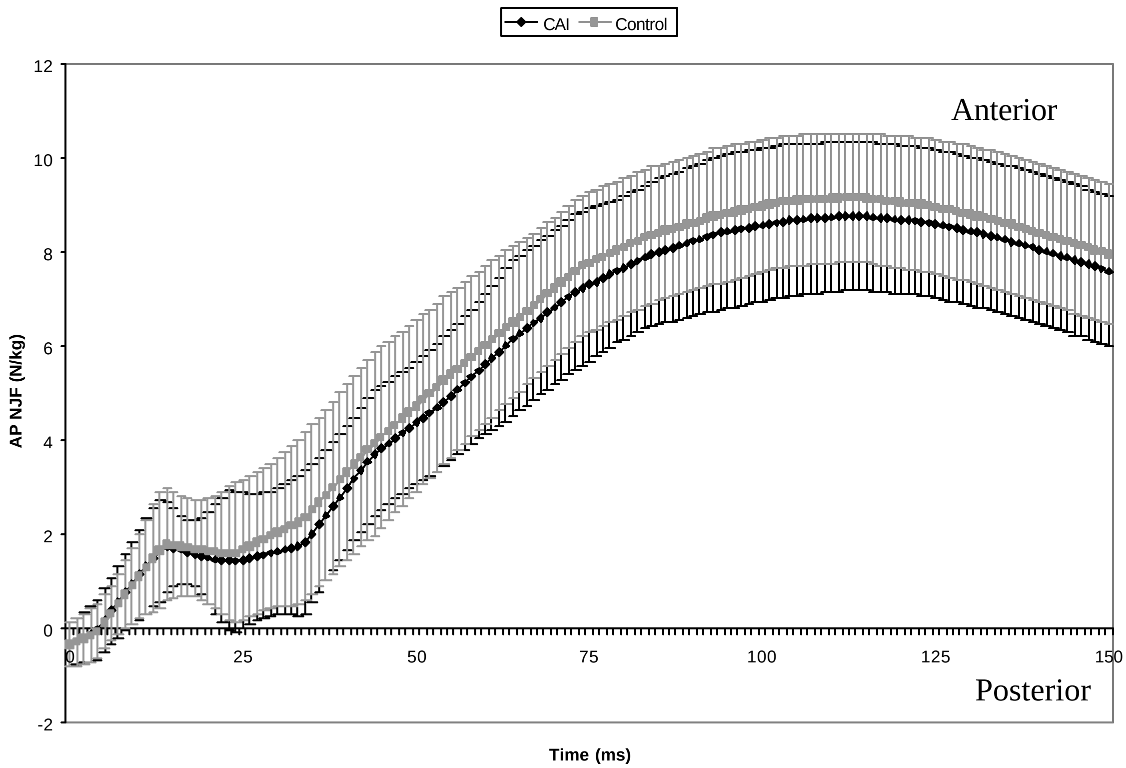


Figure 22. Mean difference and 95% confidence interval for ankle AP NJF during the cross over landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.

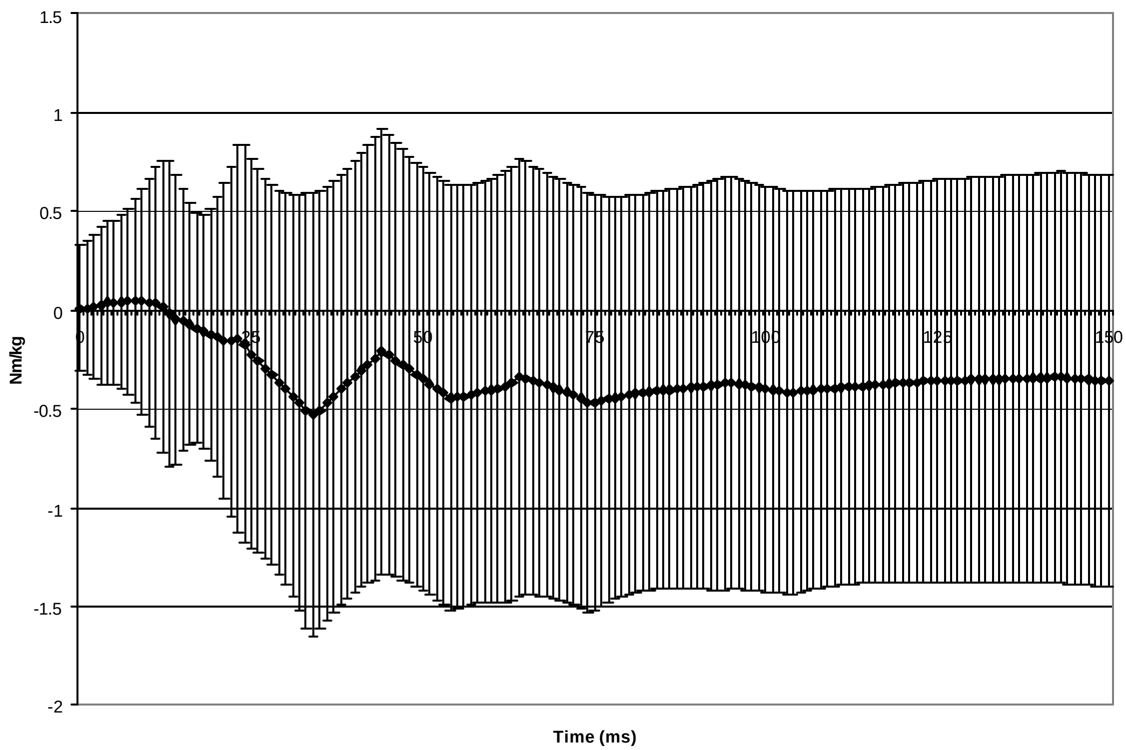


Figure 23. Ensemble averaged ankle ML NJF (N/kg) for the cross over landing task from ground contact to 150 ms after. Error bars represent group standard deviations. (positive value = lateral NJF; negative value = medial NJF)

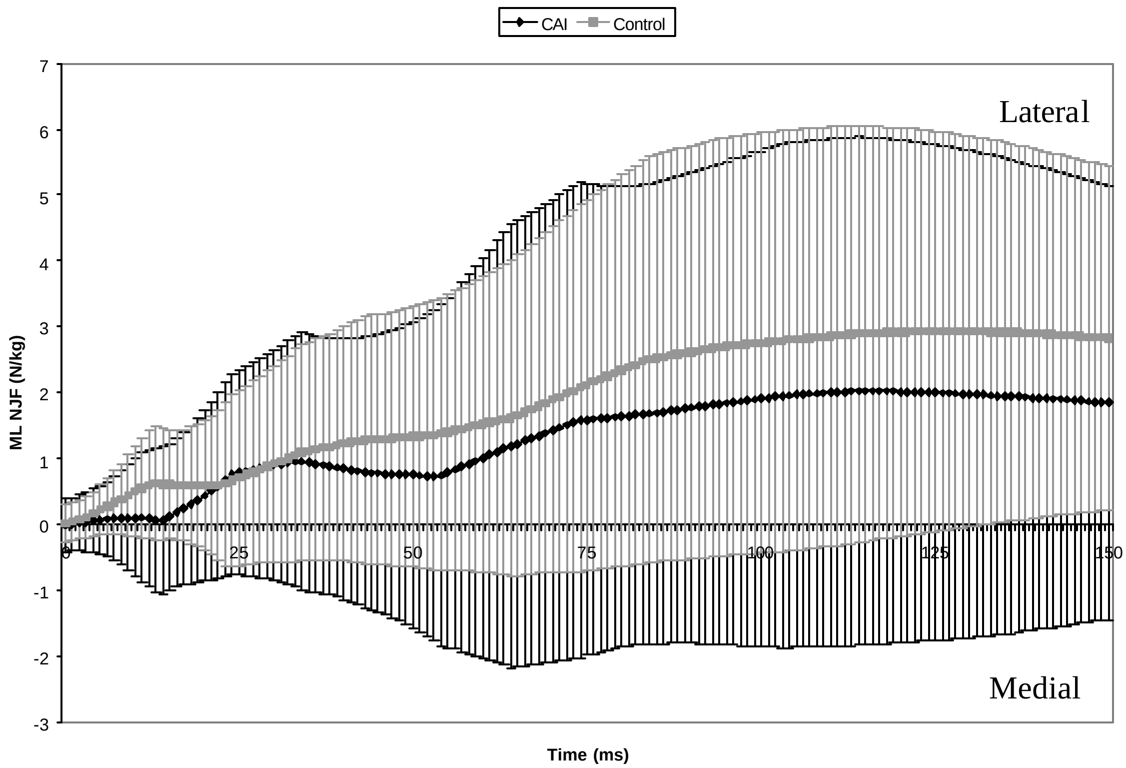
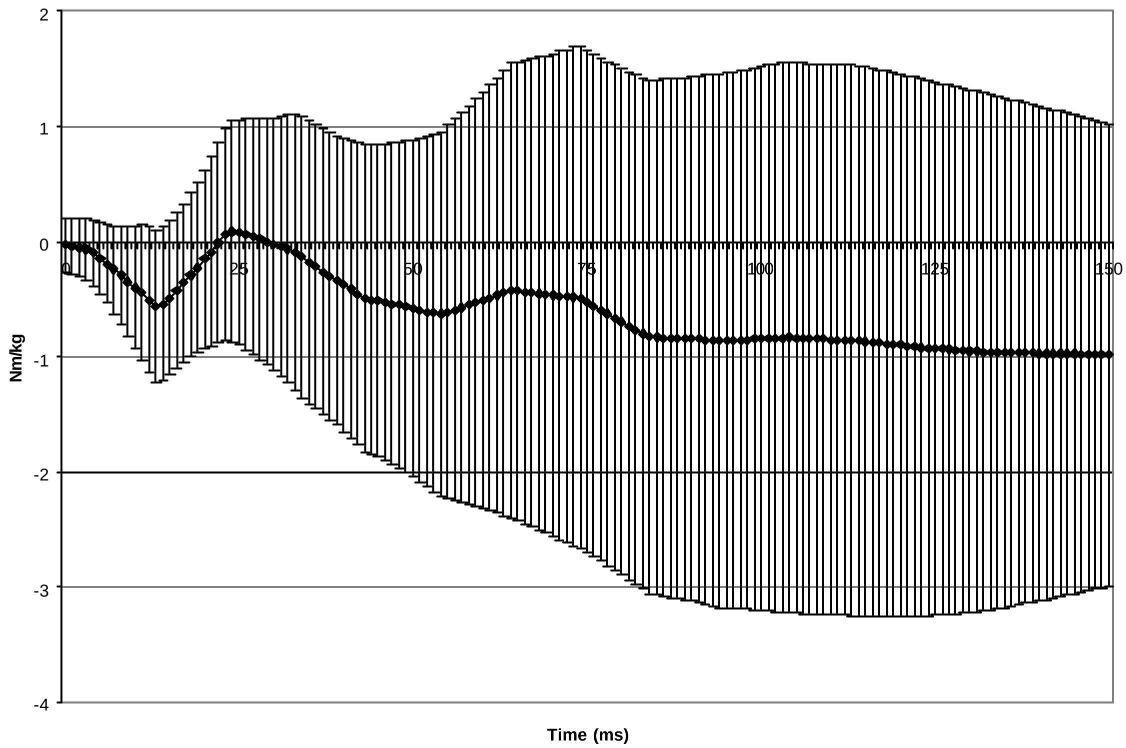


Figure 24. Mean difference and 95% confidence interval for ankle ML NJF during the cross over landing task. Mean difference is noted by solid black line, with the upper and lower limit of the confidence interval shown with t-bar.



CHAPTER 4

DISCUSSION

The purpose of this study was to determine the three-dimensional kinetics occurring at the ankle during a functional task. The most remarkable finding was that there were no significant differences between the CAI and uninjured control groups for the ankle NJM as well as the ankle NJF upon landing for both the vertical and cross over landing tasks. This was not what we hypothesized based on previous landing studies. These data represent potential findings related to motor control of the ankle during a functional task for those with CAI and an uninjured control group. It is interesting to note the high variability in ankle NJM and NJF seen for some of the dependent variables.

Vertical Landing Task

Vertical landings occur during many athletic activities (e.g. rebounding basketball, spiking volleyball, heading soccer ball). Research concerning vertical landing tasks has looked at variables upon landing from a specified vertical height. The present study aimed to mimic the vertical landing task utilized in previous studies comparing CAI and uninjured control groups by Cauffield et al. For these studies, all participants performed a step-off vertical drop landing from a height of 40 cm. Different from Cauffield et al[16], we chose to make one modification to the task by standardizing the landing height based on the participant's body height. Despite efforts to match participants, we knew there would be differences in landing kinematics and kinetics between participants utilizing varying heights. Determining landing height based on body height was one way to attempt to control the momentum gained during the vertical drop that could potentially cause differences in the way one lands, and thus NJM and NJF about the ankle.

The results of our study indicate that those with CAI are landing with similar NJM and NJF about the ankle as their uninjured counterparts. This further disputes our hypothesis that those with CAI sustain alterations in motor programming due to injury, which could further result in differences in carrying out a landing task. Our results are inconsistent with previous landing studies measuring differences in biomechanical variables for those with CAI and uninjured controls during a vertical drop landing[16, 21]. Caufield et al.[16] reported that those with CAI dorsiflexed more than the uninjured control group upon landing from a vertical drop. This position is thought to be more protective against sustaining a lateral ankle sprain. Altered peroneal activity prior to landing[21] was also found for the CAI group which is thought to predispose the ankle to injurious positions prior to landing. Different from our study, all participants in these two studies landed from a height of 40 cm. Consequently, no direct comparisons can be made.

Another study calculating biomechanical variables determined the three-dimensional NJM about the ankle, knee, and hip in those with CAI and uninjured controls during gait[23]. The only significant difference found between the groups was in the frontal plane NJM (IV/EV) at the ankle from the period of 100 ms prior to heel strike to 200 ms after heel strike. CAI participants were significantly more inverted compared to the uninjured control group. Some of our results are consistent with the findings of this study, as there were no differences between groups in net sagittal (PF/DF) and transverse plane (rotation) NJM. No direct comparison can be made as the tasks utilized in our study are more dynamic than the simple task of walking.

We also found no significant differences between groups in the NJF about the ankle at any time point upon landing. There was one study found that quantified ground reaction force during a vertical drop landing[17]. Although no significant differences were found in the magnitude of peak ML, AP, or vertical forces, there were significant differences noted in the timing of the peak forces between a CAI and stable group. Participants in the CAI group experienced a peak lateral and anterior force that was greater than the uninjured group much earlier during the 150 ms post impact.

We also expected CAI participants to land in a stiffer position of more ankle dorsiflexion (a position that is protective to lateral ankle ligaments), which has been found to result in an increase in the vertical and horizontal ground reaction forces as well as a decrease in the amount of time the force is absorbed[27, 28]. These findings were noted in small sample sizes of 10 and 9 healthy male participants respectively. These studies are different from the current one in that we examined the forces that occurred at the ankle as opposed to the ground reaction forces.

Cross Over Landing Task

The most significant finding of this task is that the CAI group landed with similar ankle NJM and NJF as the uninjured control group. Participants displayed a plantarflexion NJM upon landing. NJM in the frontal and transverse plane were more variable. On average, an IV NJM was experienced, and both IR and ER NJM were experienced throughout the period of interest. The high variability in the data during this task is interesting to note from our study. Further follow-up regarding this activity is needed to understand why this occurred.

Participants in this study performed a single leg landing in the anterior-lateral direction. We believed this task direction would challenge the CAI group more than a landing in the anterior-medial direction due to the lack of lateral support that often characterizes those with CAI[6]. This is further supported by research studying simulated gait for chronically unstable ankles[29]. Upon heel strike during normal gait, the ankle/foot complex that is substantially inverted and plantarflexed will passively stabilize itself by moving into eversion when accepting weight bearing force. It was also seen in this study that a misjudgment of approximately 10 degrees of inversion during the swing-phase placed the lateral foot in a position to collide with the ground. This resulted in maximal inversion, plantar flexion, and internal rotation of the foot/ankle complex, which could produce an injurious situation. While the study by Konradsen et al.[29] looked at simulated gait, we speculated that those with CAI might experience the same misjudgment in inversion biomechanics when moving in an anterior-lateral direction.

The lack of significant differences in NJM and NJF found during the cross over landing task is consistent with results of the vertical landing task in our study. Comparison to previous research is very limited as there were no other CAI studies found that have utilized a multiplanar jump landing task. We can, however, compare results with similar methodological studies for those with anterior cruciate ligament (ACL) injuries[30, 31]. Rudolph et al.[32] found similar kinetic & EMG variables between ACL-deficient knees and uninjured controls during a cross over landing. These results are consistent with ours for an injured and uninjured group. The study by Rudolph et al.[32] also reported greater contribution from the hip and ankle in the ACL-deficient group that allowed for similar kinetics at the knee. Different from the results of Rudolph et al, Bolgla et al.[30] and Risberg et al.[31] found differences in various biomechanical variables between a group with previous ACL injury compared to uninjured controls. Previous results were inconsistent with our results when comparing an injured and uninjured group. The results of our study may serve as a comparison for future research studying kinetics during multiplanar landings in those with CAI.

The lack of significant differences found in this study could be due to a number of factors. First, this study did not consider movements about the knee and hip. Dynamic activities, such as landing, require the work of the entire body to dissipate forces. While there may have been an alteration in the generalized motor program in our CAI group, they may have accounted for this difference by using more movement at the knee and hip to absorb forces upon landing. Previous research has shown an increase in knee flexion for those with CAI compared to an uninjured control group[16]. Our study used a small electromagnetic system designed to detect more subtle movements that may occur at the foot. Action at the knee and hip is critical for landing forces. We felt that just looking at the ankle without considering the action of the knee and hip would provide good evidence of an alteration in the motor program that occurs at the ankle regardless of what is occurring at the other joints. Because we found no differences between the groups, we may hypothesize that those with CAI have learned other adaptations (e.g. increased knee or hip flexion) to dissipate forces upon landing. These adaptations could help protect the ankle from injury.

This study utilized performance of a sub-maximal task in order to decrease gender differences. This could be another reason for the lack of significant differences between the groups. The vertical jump was performed at a height equal to 20% of body height and the cross over was performed at a distance equal to 45% of body height. These distances may have not been sufficient enough to effectively challenge the landing strategy of the participant. As indicated by Dufek and Bates[33], increases in landing height resulted in an increase in forces upon landing. Similar results were found by Zhang et al.[28]. As landing height increased, participants demonstrated larger peak ground reaction forces, peak NJM, and powers.

A third explanation for the results found may be due to variability within our participants. All participants were physically active in a number of different activities. We aimed to quantify the level of instability of our participants using the Ankle Score Scale[19], which is discussed more in depth later in the paper. While all CAI participants met the inclusion criteria, the scores on the Ankle Score Scale were rather variable. Our results contained considerable variability in the dependent variables for the unstable group, while the uninjured control group sustained relatively similar NJF and NJM. This could mean that those with CAI have learned to adapt to their condition in different ways, causing landing strategies to be different within the group. Furthermore, no data was obtained regarding previous rehabilitation for those with CAI. Individuals that were involved in an ankle rehabilitation program may have learned mechanisms to land effectively.

In determining the kinematics about the ankle upon landing, we considered the foot to be a rigid structure. While attempts have been made to quantify movement of each portion of the foot (forefoot, midfoot, rearfoot), these measurements were beyond the scope of this study. Movement and absorption of forces by other joints of the foot upon landing could allow for less inertia at ground contact, and thus decreased NJF and NJM at and across the ankle joint complex.

Ankle Score Scale

In our study, we attempted to evaluate levels of ankle instability by using the Ankle Score Scale developed by Kaikkonen, et al. (Appendix F).[19] Within ankle instability research, there is a wide range of operational definitions to classify those with CAI. To date, there have not been any research studies found that have attempted to quantify levels of instability using a published protocol to describe participants. Obtaining a specific score was not necessary to be included in this study. However, by quantifying the level of instability, we can more precisely describe our participants on an objective level. This also allowed us to see differences between the groups and differences within the groups as well.

The results of the Ankle Score Scale for the participants in this study can be seen in Table 2. According to this scale, a score of 65 or below would identify those that suffer from CAI. The mean score for participants in the CAI group is 55.28 ± 12.66, with a range of (35, 70). Participants in the healthy group earned a mean score of 82.83 ± 5.51, with a range of (75, 90). The total score earned was used to classify participants in a specific category of ankle stability, with a higher score indicating a more stable ankle (Excellent= 85-100; Good = 70-80; Fair = 55-65; Poor </= 50). There was large variability within the total score for the CAI group, with the healthy group all scoring in the Good to Excellent categories. Despite the fact that all CAI participants met all inclusion criteria, according to this scale, not all were identified as being chronically unstable. This could be one reason for the lack of significant differences found in this

study. Future research using this protocol may look to divide CAI groups into specific levels of instability before making comparisons.

The major limitation of this scale is the use of functional tasks to measure levels of instability. The CAI group scored similar to the uninjured control group for the following items: balancing, ability to walk and run normally, and rising on toes. Previous research studying functional activities has found there to be no decrease in performance for those with CAI compared to an uninjured control group[34, 35]. All participants for both groups reported the ability to walk and run normally. This is consistent with research measuring performance of a CAI and uninjured control group. Furthermore, we can hypothesize that one would retain the ability to carry-out tasks such as walking and running which are often the most simple tasks of physical activity. Therefore, the use of such tasks to determine levels of instability may be less important as other items in the scale.

In studies looking at balance, differences were found in postural stability measures, however those with CAI were able to maintain a single limb stance to complete the task[36-38]. The balance item of this scale requires the participant to maintain single limb stance for as long as possible. Furthermore, the participant keeps his/her eyes open, providing all feedback sources for maintaining balance. Balance studies, with the purpose of detecting differences in postural stability, often require the eyes closed to more directly challenge the neuromuscular system that is affected by ankle injury. Results of these balance studies are consistent with the scores of our participants for the balance item. Most participants maintained single limb stance for the maximum amount of time, with only a few scoring slightly below the maximum time.

Another scale item (rising on toes) measured the strength/fatigue of the gastrocnemius/soleus complex. These muscles are critical for absorbing forces at the ankle upon landing. Research comparing strength variables in those with CAI and uninjured controls has found there to be no differences[39, 40]. A major reason for this finding and similar results among all of our participants is the fact that rising on the toes is a common exercise for many ankle rehabilitation protocols as well as daily workout programs. Those that include this exercise in their daily activities would be expected to score higher independent of their level of instability. Unfortunately, no data was obtained on previous rehabilitation programs for the CAI group, or specific exercises performed during physical activities by the healthy group.

While there was high variability between the scores in the CAI group, the scores for most items were consistently lower than the healthy group. The most critical differences between the groups were with the subjective reporting, laxity, and dorsiflexion range of motion. According to the results found with our sample, these items may be more important in quantifying the level of instability than the other 6 items. Future research should continue to use a protocol for classifying the level of instability for CAI sufferers. Since the time of this study, other scales have been tested for their reliability and validity in determining those with CAI. The Ankle Instability Instrument (AII) developed by Docherty et al.[41] consists of a thorough questionnaire regarding ankle instability symptoms. It was found to have high reliability in self-reporting ankle symptoms. Hale et al.[42] examined the reliability and sensitivity of the Foot and Ankle Disability Index (FADI) and the FADI Sport in participants with CAI. The FADI assesses activities of daily living and the FADI Sport assesses more difficult tasks essential for participation in sport activities. Hale et al.[42] found these scales were sensitive and reliable in detecting deficits for those with CAI. They also used the FADI and FADI Sport to measure the ability of the CAI participants after participation in an ankle rehabilitation program. The FADI and FADI Sport detected improvements in function following injury. The components of the AII, FADI, and FADI Sport are different, yet seek to achieve the same goal of quantifying levels of ankle instability.

There is an immediate need to precisely define participants for ankle instability research. Scales like the three previously discussed can be used as a tool to screen participants and quantify levels of instability. Future research should continue to measure the sensitivity and reliability of these scales so a model can be formed for those interested in studying CAI. This would further contribute to the clarity for those comparing studies with different CAI operational definitions. Finally, with more objective measurement tools, a better understanding of CAI may be found.

Table 2. Ankle Score Scale Results. Average and standard deviation (given in parentheses) of measurement for each item and average and standard deviation of points scored for each item. (Sx = symptoms)

	Control		CAI	
Item	**Measurement**	**Score**	**Measurement**	**Score**
Subjective	100% No Sx	15 (0)	17% Mild Sx 72% Moderate Sx 11% Severe Sx	5.27(2.70)
Walk Normally	100% yes	15 (0)	100% yes	15 (0)
Run Normally	100% yes	10 (0)	100% yes	10 (0)
Stairs (Time in seconds)	12.45 (1.34)	0.28 (1.18)	14.0 (2.33)	0.28 (1.18)
Rising on Heels (# of reps)	36 (6.95)	6.94 (3.89)	25.22 (14.08)	3.61 (4.13)
Rising on Toes (# of reps)	35.17 (7.55)	6.67 (4.20)	31.56 (7.77)	3.67 (3.38)
Balance (Time in seconds)	56 sec (0)	10 (0)	50.76 (11.06)	7.5 (3.93)
Laxity (Anterior Drawer Test)	89% Stable 11% Moderate	9.44 (1.62)	22% Stable 67% Moderate 11% Severe	5.56 (2.91)
Dorsiflexion ROM (degrees)	11.28° (4.0)	9.17 (2.57)	6.39 (3.11)	4.44 (3.79)
Total Score		**82.84 (5.51)**		**55.28 (12.66)**

Conclusions

According to the results of our study, there appears to be no alteration in the motor program about the ankle for those with CAI compared to uninjured controls. This suggests that those with CAI are not encountering increased ankle NJM or NJF magnitudes predisposing them to injury more often than an uninjured individual. This is just one study that has quantified three-dimensional ankle kinetics upon landing for those with CAI, so further evidence is needed to support this conclusion. With similar results for NJM and NJF about the ankle between those with CAI and uninjured individuals, clinicians should consider the motor control of the entire kinetic chain that may be affected by an ankle injury. Future rehabilitation programs for those that have suffered an ankle injury should look to include landing activities that focus on coordination of the entire body, not just at the ankle.

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APPENDIX A

RESEARCH HYPOTHESES

(1) There would be a significant difference between the chronic ankle instability group and the uninjured control group in plantarflexion/dorsiflexion, inversion/eversion, and adduction/abduction net joint moments during the vertical landing task.

(2) There would be a significant difference between the chronic ankle instability group and the uninjured control group in axial, medial/lateral, and anterior/posterior net joint force during the vertical landing task.

(3) There would be a significant difference between the chronic ankle instability group and the uninjured control group in plantarflexion/dorsiflexion, inversion/eversion, and adduction/abduction net joint moments during the cross over landing task.

(4) There would be a significant difference between the chronic ankle instability group and the uninjured control group in axial, medial/lateral and anterior/posterior net joint force during the cross over landing task.

OPERATIONAL DEFINITIONS

(1) Chronic Ankle Instability- Participants will be considered to have chronic ankle instability of one of their ankles as described by: 1) The initial sprain was moderate to severe and required medical attention; 2) Experienced at least two moderate ankle sprains (required medical attention) to the same ankle no more than 12 months ago, but greater than four weeks before this study; 3) Experienced weakness and/or pain from this sprain before, but completely asymptomatic at the time of this study.

(2) Mechanical Instability- This is the actual clinical laxity of a joint, in which movement is beyond the physiological limit of the joint. May also refer to this as anatomic laxity which means a ligament has been overstretched, and there is an increase in the accessory motion of the ankle {Denegar, 2002 #8}.

(3) Functional Instability- the tendency of the ankle to "give way"; joint motion beyond voluntary control, but does not exceed the physiological limit.

(4) Physically active- Participating in physical activity at least three days a week for 20 minutes in duration, and a score of five or better on the Tegner and Lysholm{Tegner, 1986 #45} activity level questionnaire.

ASSUMPTIONS

(1) The participants provided accurate & honest information about their history of injury.

(2) Participants gave maximum effort on every trial during every task.

(3) Performance of each task mimicked the participant's live performance of the task.

(4) There were no gender differences among the variables.

(5) All participants have participated in similar forms of rehabilitation after injury.

(6) All participants in each group landed with similar kinematics at the hip and knee.

LIMITATIONS

(1) There was a lack of random sampling due to the use of a deliberate sample.

Participants were selected according to specific criteria to ensure the accuracy and validity of the results.

(3) Participants performed tasks barefoot which is unlike a typical functional activity where shoes are worn.

(4) The foot was assumed to be a rigid structure; movement of the forefoot and midfoot was assumed to not contribute to the landing strategy of the participants.

DELIMITATIONS

(1) The sample of participants only consisted of physically active individuals attending classes at Georgia Southern University.

(2) Any participant with a previous history of surgery or fracture to either ankle was unable to participate.

(3) While all the tasks simulated functional activity, tests were carried out in a controlled lab setting where the participant had prior knowledge to the jump being performed.

APPENDIX B

Chronic ankle instability (CAI) continues to be a debilitating factor for the physically active population.[1] CAI is characterized by the occurrence of repetitive bouts of lateral ankle instability, which results in numerous ankle sprains.[2] As the incidence of lateral ankle sprains (LAS) remains to be the most common injury sustained by the physically active population[3, 4], the development of this residual impairment is of major concern. Many will seek rehabilitation following injury, but will still experience symptoms long after the initial injury[1, 5]. It has been reported that between 55% and 72% of those that have sustained a LAS experience residual symptoms within 6 weeks to 18 months after the initial injury.[1, 5] Studies of a general population revealed that 20% of those that experienced one ankle sprain reinjured their ankle within 18 months of the initial injury. Also, nearly 40% experienced at least 1 moderate to severe symptom at a six month follow-up.[5]

The ankle joint is a very complex, dynamic structure. Thus, trying to identify one underlying factor in the development of CAI is nearly impossible. CAI can be broken down into two potential contributing factors: functional instability and mechanical instability.[2] Specifically, functional instability refers to the repeated giving way of the joint during functional activity. Mechanical instability is the pathologic laxity where joint motion is beyond that of the physiological limits.[2] Within these two factors lies a plethora of possible pathologies that could contribute to the development of CAI. These factors include strength deficits of the musculature surrounding the ankle, increased peroneal reaction time to joint perturbations, and decreased proprioception and joint position sense.[2] They have been heavily studied in an attempt to create an explanation for the development of CAI.

Previous research has focused on examining the proposed factors in isolated conditions, whereas ankle sprains occur during functional activities. Results of these studies have failed to be consistent. The next step is to examine those with CAI during functional tasks. Landing is an essential component for many sporting events. The forces involved with various landing strategies could predispose athletes to injury during landing activities. Ankle injuries have been reported to occur more frequently upon landing than any other task.[6] To date there have been a few studies to quantify the kinematics,[7] ground reaction force,[8] and muscle activation of CAI participants during landings.[9] However, no studies have measured the kinetics in CAI patients during landing. Kinetic analyses will give some indication of the necessary eccentric muscle action and load distribution that occurs during landing. This data will provide evidence of ankle joint complex force distribution patterns and whether altered patterns exist in CAI patients .

Currently, there is a limited amount of research that involves performance of a functional task in those with CAI. A couple studies have measured functional performance in those with CAI.[10, 11] Munn et al.[11] conducted a bilateral performance comparison during a triple cross over hop for distance and six meter shuttle run. They used a self-report ankle score to determine those with unilateral ankle instability. Participants reported levels of pain and instability during functional activities, swelling, and the ability to perform various weight bearing activities. This scale demonstrates instability that is perceived by the participant. It is highly subjective, and the participants' levels of perception can vary greatly. The participants that were defined as having unilateral instability reported scores that ranged from thirty-eight to ninety-five out of a possible one hundred. The study revealed no significant differences in the performance between the healthy and injured sides for either task, although there were differences detected by the questionnaire. The outcome measures, distance and time, were the only data collected during the functional performance tasks. There was no kinematic or kinetic data collected that may have suggested differences in the way the tasks were carried out. In a similar manner, Demeritt et al.[10], using outcome measures of time and the number of performance errors committed, also failed to reveal differences between a group of self-reported CAI patients and an uninjured matched control group.

Although there were self-reported differences between the testing groups, data from Demeritt et al.[10] suggests that compensatory patterns can occur that allow the joint to carry out functional tasks without hindering performance. While those with CAI may perform at similar levels to healthy people, there remains to be the question of why they are sustaining ankle injury more frequently. Further research needs to consider the kinetics during functional tasks in order to determine the distribution of forces that put CAI sufferers at an increased risk for injury.

LANDING STUDIES

Ground Reaction Force

Measuring ground reaction force (GRF) demonstrates the amount of loading on the body that is taking place during impact. The weight force of the person acts in a downward direction, and the GRF is upward upon impact.[12] It is a reflection of the acceleration changes of the body's center of mass upon landing as the body tries to bring itself to a vertical force of zero. In general, the GRF may be equal to the person's weight, however the magnitude of GRF often varies due to muscle activation, and the position of the body upon landing. Thus, a larger peak magnitude GRF, especially those more than the person's body weight would indicate higher load application to the body, which could possibly put a person at risk for injury.

Studies of vertical GRF during landing in healthy participants have shown GRF to be correlated with lower extremity kinematics.[13-17] GRF was determined during single leg landings from various heights ranging from thirty centimeters to one hundred centimeters. Self et al[16] , Hargrave et al.[15], and Zhang et al.[17] showed a direct relationship between vertical GRF and knee flexion angle. As knee flexion increased (less stiff landing), vertical GRF decreased. In contrast, Decker et al.[13] did not show a relationship between knee flexion and vertical GRF, but rather a decrease in GRF at initial ground contact with more plantarflexion at the ankle. This finding of plantar flexion influence was also demonstrated in the study by Self et al.[16] The more stiff (hip and knee extended and ankle dorsiflexed) the legs are upon landing, vertical GRF is going to be applied at a quicker rate, and force primarily absorbed at the ankle. With the lower leg in an extended position, forces are first absorbed and distributed at the ankle as it makes initial contact with the ground. Decreased movement of the knee and hip results in a decreased contribution of these joints to dissipate forces upon landing.[18] Furthermore, the study by Self et al.[16] found there to be a slight decrease in GRF during landing in which ankle plantarflexion was stressed while keeping the knee as straight as possible when compared to a natural landing where knee flexion accounted for most of the energy dissipation.

Vertical GRF was also shown to increase with increases in the height of landing.[17, 19] Thus, ground reaction forces upon landing have a relationship with lower extremity kinematics and height of landing. More motion in the lower extremities including knee flexion and ankle plantarflexion is the most beneficial landing position when trying to minimize vertical GRF.[13-17] These actions become more important as the landing height increases. Landing height increases can change the way in which a person lands, due to the momentum build-up prior to landing. As the height increases, the body must dissipate larger forces utilizing more. With increases in height, there is a subsequent increase in duration of force resulting in an increase in momentum.[12] The momentum of mass (the person) increases, and thus becomes critical in the amount of GRF. Differences in the resultant GRF can be attributed to the mass of the person and momentum gained upon landing. To produce accurate results of force dissipation upon landing, it may be necessary to individualize the landing height for all participants. Each participant will be experiencing similar amounts of force per his/her body mass. The GRF measured will consequently be a result of the way the person landed, not an effect of landing height.

Cauffield et al.[8] is the only study to quantify GRF for CAI participants during landing. Participants (CAI and control group) performed a single leg landing from a height of forty centimeters. The magnitude and time of peak medial/lateral, anterior/posterior, and vertical forces were measured and averaged for 150ms following impact. Although there were no group related differences in peak GRF forces, the peak medial/lateral and anterior/posterior GRF occurred significantly earlier in the CAI group resulting in an increased loading rate. There was also a significant difference in the magnitude of the time averaged forces during the initial 150 ms post impact as the injured group vertical GRF differed by up to one hundred percent of body mass. These differences provide evidence that those with CAI may be landing differently than healthy participants. We can hypothesize that those with CAI possibly land in a more dorsiflexed position that is more protective in maintaining a stable position for the talus. A lack of plantarflexion upon impact will increase vertical GRF. It also decreases the ability of the body to readily absorb impact forces resulting in a decreased time to peak forces for those with CAI.

Based on other GRF studies, these differences in GRF measures could be due to differences in kinematics of the lower extremity upon landing. There was however no differences in the peak GRF, so similar forces are being applied for both groups. The quicker rate of loading provides evidence that those with CAI are unable to dissipate forces as efficiently as a healthy person. No three dimensional measures of kinematics or kinetics were made which could have provided further explanation on where the forces were occurring for the CAI participants.

Differences in plantar surface force distribution between healthy and CAI participants has also been demonstrated during walking.[20] The CAI group demonstrated a significant decrease in the relative forces under the heel and toes and an increase in relative forces under the midfoot and lateral forefoot compared to the control group. There was a significant delay to the time of peak force under the central forefoot, lateral forefoot, and toes in the CAI group. As well as significantly longer contact time of the heel and midfoot areas in the CAI group. Differences in force distribution suggest an altered gait pattern from normal participants. These differences could occur due to compensatory mechanisms needed in the CAI group for stability during walking. As a result of the initial injury, those with CAI may have developed compensatory patterns that now govern the way a particular movement is performed.

The increase in relative forces under the lateral foot could potentially be a result of CAI. Those with CAI have a lateral instability. The person may have a decreased ability to dissipate forces laterally during walking compared with a healthy ankle. Altered sensory input from the mechanoreceptors in the ankle may contribute to the different output seen during gait. Another explanation for the different force distribution is that there is an alteration in the generalized motor program for walking. The program has become altered in order to provide a walking pattern that limits feelings of instability. With forces being dissipated in 150 ms, reflex activation of dynamic restraints at the ankle is insufficient, suggesting that dynamic control can more readily be achieved by feed-forward mechanisms. This could provide evidence that differences may occur in other functional activities. If alterations are occurring during a simple task as walking, we could hypothesize that more dynamic activities could produce differences as well.

Muscle Activation Patterns

Muscle activation patterns can provide information about the activity occurring about a joint during a functional task. Studying electromyography (EMG) signals can provide evidence of the amplitude and frequency of muscle activity. Based on the amplitude of the EMG signal, muscular force a muscle can generate can be determined. It can also provide us with evidence of the onset of activation among various muscles during a specific task. EMG does not directly provide evidence that movement has occurred, or muscular control. Kinematic data must also be included to show the movement that is potentially produced by muscular activity. Combining EMG data of amplitude and onset of muscle activation with kinematic data helps to determine coordination patterns, as we can see which muscles are activated as the joint segments move.[12] EMG is not sufficient in providing data regarding the amplitude or strength of muscle contraction, and its ability to provide movements. There are many limitations when measuring and analyzing EMG signals. When trying to determine force, kinematic data will also need to be collected to determine what movements are taking place. There can also be a considerable amount of crosstalk, as it is very difficult to isolate just one muscle. Signals can be detected by electrodes adjacent to muscles not specifically being examined.[12]

Adequate muscle activation is necessary in order to stabilize the ankle joint complex upon landing in an attempt to prevent ankle injury. Electromyography studies of the lower extremity during functional tasks show the peroneal muscles may play a key role in stabilizing the ankle upon ground contact.[21, 22] Reber et al.[22] determined muscular activity during running. They found a significant increase in activation of the peroneus brevis as running pace increased. Assuming impact forces are more rapidly applied to the foot with increases in running speed, the peroneal muscles must contract more forcefully to stabilize the foot.

Neptune et al.[21] studied muscle coordination and function during cutting movements that utilized lateral movement. Similar with Reber et al.'s[22] results, their data seemed to suggest the peroneus longus (PL) plays a significant stabilization role during a side shuffle activity. EMG and kinematic data was collected fifty milliseconds prior to impact until time of toe-off. The PL showed a high burst of activity before impact with increases in activity after touchdown to help decelerate the rapid supination of the foot which was measured to be forty-five degrees just before impact. Activity of the PL remains high during midstance to protect the ankle throughout the side shuffle movement. There was also a burst in GAS activity prior to landing, while for some the tibialis anterior showed a burst in activity at this time as well. The co-contraction of these two muscles would suggest a stabilizing role for the foot in a upon landing.[21] The foot moves into dorsiflexion after ground contact, until just before toe-off when it plantarflexes to push off. The kinematic and EMG analysis by Neptune at al.[21] provides baseline data for the function of the lower extremity during a cutting movement. Significant to note is the activity of the lower extremity muscles prior to landing. As studies have shown that reflex activation is not fast enough to prevent ankle sprains from occurring, activation prior to impact can be more beneficial in decelerating loading forces during landing. Activation of the muscles prior to impact helps to decrease the electromechanical delay, allowing activity of the muscle upon impact to occur faster.[23] This concept will be discussed later in the review.

Stability of the ankle via the peroneals during functional movements is critical. As demonstrated by the previous studies, the peroneal muscles were activated throughout the movement to maintain lateral stabilization of the ankle.[21, 22] During many functional activities, the initial contact of the foot with the ground is in a plantarflexed and supinated position. Peroneal activity via eccentric contraction is responsible for slowing down the movement as the foot moves into pronation. Proper activation will also help to keep the joint from moving farther into supination.

Studies of muscle activation in CAI participants show altered peroneal activity during walking[24] and vertical jump landing.[9] Santilli et al.[24] found a decrease in the mean activation time of the PL during the stance phase of walking in the unstable ankle compared to the contralateral healthy side. Cauffield et al.[9] measured EMG activity of the PL before and after impact of a vertical jump and forward jump for distance in participants with CAI and uninjured controls. There was a significant reduction in PL EMG prior to landing in both jumping activities. The insufficient muscle activation does not help to stabilize the lateral joint upon landing, as vertical forces are absorbed and dissipated by the ankle plantarflexors. This altered activation can thus put a CAI sufferer at risk for recurrent ankle injury.

Kinematics

As illustrated in previous research, the kinematics of the lower extremity influence the forces imparted upon joints during landing. A less than optimal joint position upon landing changes the load distribution imparted upon the lower extremity joints. Any deviation therefore may increase their vulnerability to injury. It has been suggested that altered joint positioning of the ankle during ground contact can predispose the person to ankle injury.[25-27] Wright et al.[26] examined the influence of foot positioning at touch-down during a side shuffle movement on ankle sprain occurrence. They concluded that a more supinated or plantarflexed position at ground contact was associated with occurrence of more ankle sprains. Konradsen et al.[27] determined the effect of inversion biomechanics during gait on occurrence of ankle sprains in cadavers. During simulated heel strike, the ankle was placed in substantial inversion and plantarflexion, but the ankle joint was able to stabilize itself by moving into eversion as weight bearing increased. However, during swing phase, the inverted ankle of approximately ten degrees collided with the ground and resulted in a maximal plantarflexion and inversion stress at the ankle complex.

Kinematics have been measured during a vertical landing in participants with CAI.[7] Those with CAI showed significant differences in the angular displacement of the knee and ankle prior to and immediately following a drop landing from a height of forty centimeters. The CAI group demonstrated less plantarflexion before contact, increased dorsiflexion at and after contact, and greater knee flexion before, at, and after ground contact. This altered position of less plantarflexion may be an adaptation that has occurred to control residual impairments from previous ankle injuries. Because lateral ankle sprains often occur with the foot plantarflexed, the CAI sufferer may be more reluctant to place the foot in this vulnerable position to protect the anterior talofibular ligament.[25]

Kinetics

Proper dissipation of forces upon landing is a critical component to functional activity. When studying landings, analysis of the kinetics can provide the most accurate information of the net joint forces and moments at a particular joint. The net forces and moments represent the sum of the action of all joint structures. This is critical, as landing forces have been found to be much larger than the force of a participant’s body weight.[19] Landing requires movements to dissipate energy while work is being performed on muscles of the lower extremity.[14] Joint moments of force can be used to describe mechanisms that help dissipate energy upon impact.

Kinetics examines forces and the cause of movement.[12] Forces represent the action of one object on another, and are necessary for movement. Movement of the human body occurs due to the application of external forces through direct contact with the ground or an object, as well as internal forces. In the human body, we have many sources of internal forces (muscles, ligaments, tendons, joints) that characterize how the body functions. There is no easy and convenient way to directly measure the forces that occur at each joint, muscle, ligament, etc. Measuring kinetics utilizes inverse dynamics to calculate the net effect of all the internal forces and moments of force acting across several joints. Net forces and moments represent the sum of the actions of all the joint structures. The net force is the sum of all forces that act across a joint. The net joint moment is a summary representation of the relative effort of a particular joint and movement. It is not the effect of a particular muscle, as the force created by a single muscle cannot directly be measured. Muscles contribute to the net moments of force, but it is a sum of all forces. Segment information, ground reaction forces, segment kinematics, and anthropometric data are analyzed to calculate three-dimensional kinetics.[12]

Various studies have measured kinetics during drop landings. The tasks in the studies consisted of a combination of drop heights, and utilized different landing techniques. Landing techniques were described as either soft or stiff, and were based on the angle of the knee at landing. More stiff landings were associated with less knee flexion upon impact and soft landings used substantial knee flexion when landing. Studies during vertical drop landings showed increases in the net joint moments when participants landed in a stiffer position (less knee flexion).[14, 17, 19] Also, when using a stiffer landing technique, there is an increased contribution at the ankle in the absorption of impact forces, with the hip demonstrating a significantly less contribution. Devita et al.[14] also found a significant difference for time of the impact phase between the soft and stiff landing. Forces were dissipated in the soft landing after 130 ms whereas the stiff landing absorbed the impact in 88 ms. With a stiffer landing, the joint has less time to dissipate the force, producing a larger net joint moment. As the ankle hits the ground in a more dorsiflexed position, this increases the net joint moment at the ankle.[19]

Similar increases in joint moments are also seen when landing on a flatfoot compared to toe-heel landing.[18, 28] A flatfoot landing places the joints in a stiffer position with less range of motion, and consequently less activity and contribution from all the joints. During a toe-heel landing, two GRF and joint moment peaks are demonstrated: one at initial contact with the forefoot and another with contact of the heel. The ankle shows significantly higher values at the second peak[28]. During a flatfoot landing, there is often only one peak as most of the force is absorbed upon impact. Dufek et al.[18] found landing height to contribute more to the first moment and force peak, whereas landing technique influenced the values more at the second peak.

Increases in net joint moments are also associated with increases in landing height.[17-19] As landing height increased, each joint displayed an increase in work to dissipate forces upon impact.[17] The joints still demonstrated similar relative contributions during landing from different heights. Furthermore, landing heights of sixty centimeters and above were found to be harmful to the body as it is less able to control the impact forces. [18, 19]

A major limitation with kinetic research is that most all of kinetic research has only reported sagittal plane variables. One study was found that measured three-dimensional kinetics during running.[29] Peak moments were calculated for the rearfoot in three planes of movement: sagittal, frontal, and transverse. The moments of the ankle upon contact with the ground were largest in the sagittal plane. Participants demonstrated a brief dorsiflexion moment followed by a plantarflexion moment throughout the rest of the stance phase. The brief dorsiflexion moment demonstrates shock absorption, while the plantarflexion moment was probably due to the participant beginning to push-off, and continue the running motion. Smaller moments were calculated in the frontal plane, with an inversion moment maintained throughout contact. There was moderate variability in this measure across all subjects. The moment of the transverse plane was very small and variable. The large variability in the frontal and transverse moments calculated may have occurred due to the placement of the tracking markers. Participants wore shoes for testing, and the markers were placed on various aspects of the shoe to detect motion of the foot. Motion in the frontal and transverse plane is rather delicate, and would be difficult to detect in this manner. While many injuries occur due to movements in the frontal and transverse plane, further research is needed that considers three-dimensional kinetics during functional tasks. To date, there have been no studies found that have quantified kinetics of the ankle for those with CAI during functional tasks.

GENERALIZED MOTOR PROGRAM THEORY

The various alterations in the normal functioning of the joint prior to landing as demonstrated by previous research may be the result of damage to the generalized motor program (GMP) responsible for landing technique. Research has shown that feedback mechanisms via peroneal muscle activation are not adequate in preventing ankle sprains from occurring[30] This is especially true as critical aspects upon impact landing occur before the body has time to react. With reflex activation, there is an associated latency period from the moment of sensory stimulation and a motor response. Also, concerning the latency period is electromechanical delay. This is the time from when the muscle begins to depolarize and when we actually see force created by the muscle to move a segment.[23] Due to these delays, it takes a fairly substantial period of time for the dynamic restraints to provide counter movement at the joint during perturbation. Thus, reflexes are largely ineffective for maintaining joint stability, and we must then look to other explanations for alterations that occur prior to, upon impact, and after landing.

A GMP is a set of "rules" that govern how a particular task will be carried out. It explains how motor control is going function. Each GMP has certain invariants and parameters that define the motion. The invariants are the fixed features of the program. They explain the order of the events that will take place, the timing of these events, as well as the relative force. The parameters define specific muscles and joints that will be used, the overall duration, and overall force of activity. Each program is based on a central mechanism that is specific to an action, not a particular body segment.

In order for the body to successfully reduce forces during impact, we must look to the particular sequence that commands the GMP for landing tasks.[31] Landing is a complex skill that is highly reliant on the function of the entire lower extremity to dissipate forces upon impact that are least harmful to the body. When injury occurs, an alteration in the GMP may occur to compensate for the damaged structures. When one sustains an injury, damage to articular, muscular, and cutaneous mechanoreceptors alters the sensory input and thus the resulting motor output and motor program.[23] Consequently, an alteration in the central governing GMP will affect the action of both sides of the body no matter if injury has only occurred to the right or left side.

GMP theory is further supported in literature that attempts to compare variables in participants with unilateral ankle instability to their contralateral healthy leg. Conflicting results were seen in two studies that attempted to measure joint position sense in those with CAI. A study by Hubbard, et al.[32] measured joint position sense for in participants with unilateral CAI and compared the results to the contralateral uninjured limb. Subjects had to reproduce inversion and eversion positions with and without various bracing devices on the ankle. They found no significant differences in the time to detect the motion between the CAI group and their contralateral control limb. Opposite to the results of this study, Refshauge et al.[33] found significant differences in joint position sense for participants with recurrent ankle sprains compared to an uninjured control group. The participants in this study had to detect passive inversion and eversion movements at the ankle. Control participants were able to detect smaller movements, whereas the CAI group initially detected movement at larger ranges of inversion and eversion.[33]

Similar findings can be seen when comparing studies that measured peroneal reaction time to sudden inversion stress in unilateral CAI and the contralateral healthy limb. These studies have found no significant differences in their measures between the injured and uninjured limb.[34, 35] However differences were noted when comparing a CAI group to uninjured controls.[35] This further supports the idea that GMPs become altered with injury. Nyska et al.[20] compared a CAI group to a control group, as well as those with unilateral CAI and their uninjured contralateral limb. They found differences between the CAI and control group for force distribution during walking, although no differences were detected when comparing the unilateral CAI to the uninjured limb.

CHRONIC ANKLE INSTABILITY

A significant problem within the literature is the way in which the author defines chronic ankle instability. Until just recently, researchers have often used the term "functional ankle instability (FAI)." When defining this term, the actual mechanical laxity of the joint is not included. One may have FAI without mechanical instability, and vice versa, which further complicates how study participants are defined. Also, naming participants as having FAI is often from a subjective measurement. Diagnosis of FAI is solely reliant on information from the participant. Thus participants in the unstable group could present with varying degrees of instability however they are all being compared equally. Recently, the term chronic ankle instability is being used to encompass all aspects of instability at the ankle joint complex, including factors associated with mechanical instability, as well as factors associated with functional instability.[2] Because CAI is such a multifaceted phenomenon, objective measures to diagnose this have not been determined.

Another complication within CAI is the participants studied. Many authors have compared unilateral CAI with the contralateral healthy limb. Based on the generalized motor program theory discussed earlier, this subject population is not accurate in determining differences in those with CAI compared to a healthy group. For individuals with unilateral instability, similar patterns during functional activities occur on the contralateral healthy limb due to the function of a central motor program. This population does not adequately reflect two distinctly different groups when trying to measure differences and make comparisons. They often have similar functional levels, and the differences do not sufficiently reflect alterations that may result from CAI.

Consequently, the lack of a consistent CAI definition makes it challenging to compare all ankle instability studies, and thus no definitive conclusions can be drawn concerning our understanding of ankle instability. Criteria need to be very precise and only study those with similar characteristics. Therefore, future research should establish a more objective, universal definition that all research studies will use when examining this phenomenon.

CLINICAL RELEVANCE

Previous research has been dedicated to studying numerous variables hypothesized to contribute to CAI in isolated conditions, and has produced inconsistent findings. The major limitation in the applicability to ankle sprain occurrence is that none of these variables were studied during a functional task, which is when ankle sprains occur. There are numerous studies that have quantified variables during functional tasks, however participants with CAI were not included in much of this research. Furthermore the few studies quantifying variables during landing in those with CAI have only considered one dimension of movement (sagittal plane). Many functional activities require multiplanar movement with conceivably large amounts of shear force that could potentially contribute to repetitive bouts of ankle instability. There are no studies to date that have measured kinetics during landing in CAI participants. Quantifying the kinetics during landing will help to determine the amount of shear force and its effects on the ankle joint complex, as well as the distribution of force across the ankle joint to dissipate energy during landing activities.

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APPENDIX C

GEORGIA SOUTHERN UNIVERSITY

JIANN PING HSU SCHOOL OF PUBLIC HEALTH

CONSENT TO ACT AS A PARTICIPANT IN AN EXPERIMENTAL STUDY

Title: Ankle Kinetics in the Frontal & Sagittal Plane during Landing Tasks in Participants with Chronic Ankle Instability & Uninjured Controls.

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PURPOSE OF STUDY

This study is designed to compare landing strategies between healthy individuals and persons with chronic ankle instability. Specifically we seek to examine the forces the ankle experiences during different types of landings.

PROCEDURES

Participation in this study will require you to attend one testing session (45 minutes). During the test session, you will perform four different single leg landing tasks. Each task will be repeated five times. The first task is a vertical landing from a height equal to 20% of your body height. You will use the non-test limb to propel yourself off the platform and onto the forceplate. The second task is a diagonal hop. The target distance for the jump will be equal to 45% of your height. The jump and landing for the will be carried out by the test limb. Special sensors that use electromagnetic energy will be attached to your back, upper and lower legs and feet using tape. The cords from the sensors are attached to a personal computer. In addition, the tasks will be performed over a specialized surface that collects data regarding the forces you exert against the ground.

RISKS

The risk assumed during the testing is mild. To minimize the risk of injury, all procedures will be explained and a video demonstration will be given. You will be allowed to practice the tasks until you feel comfortable. Only trained personnel will be conducting the tests. You should also understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. In addition you understand that you are not waiving any rights that you may have against the University for injury resulting from negligence of the University or investigators.

BENEFITS

There are no known benefits to you for participating in this study. However, there is a great amount of societal benefit. The adverse effects of lateral ankle sprains and chronic ankle instability continue to affect many physically active individuals. Proper rehabilitation programs continue to be a necessary component to prevent further sprains. While previous research and rehab protocols have shown no decreases in the occurrence of ankle sprains, the proposed results of this study could provide a new insight on other components to consider with ankle instability and rehabilitation. Thus, more effective rehabilitation protocols could be implemented.

DURATION/TIME

The total amount of time testing will take about 45 minutes for a one time only testing session.

CONFIDENTIALITY

You understand that any information given will be handled in a confidential manner. Your identity will remain confidential throughout the study by assigning a case number to all records. You will not specifically be mentioned in any research publication. In some cases, research records may be inspected by appropriate government agencies or released to an order from a court of law. All information and research records will be kept for a period of five years after the termination of this study.

RIGHT TO ASK QUESTIONS

You have the right to ask questions and have those questions answered. If you have any questions about this study, please contact the researcher or faculty advisor named above. For questions concerning your rights as a research participant, contact Georgia Southern University Office of Research Services and Sponsored Programs by e-mail oversight@georgiasouthern.edu or call (912) 486-7758.

VOLUNTARY PARTICIPATION

You understand that you are volunteering to participate and are not required to take part in this research study. You have the right to withdraw at any time. You may discontinue participation at any time by informing the PI. You do not have to answer any questions that you do not want to. You also understand that you may be removed from the research study by the investigators in the event of an inability to complete the testing procedures.

PENALTY

There is no penalty for deciding not to participate in the study. You may decide at any time that you don't want to participate, and withdraw without penalty or retribution. Your decision to participate in the research study or withdraw from participation will have no effect on your status with the Georgia Southern University or any other benefit to which you are entitled.

VOLUNTARY CONSENT:

I certify that I have read the preceding information, or it has been read to me, and understand its contents. Any questions I have pertaining to the research have been, and will continue to be answered by the investigators listed at the beginning of this consent form at the phone numbers given. Any questions I have concerning my rights as a participant will be answered by the Georgia Southern University IRB Office (912-681-5465). A copy of this consent form will be given to me. You must be 18 years of age or older to consent to participate in this research study. I understand that medical care is available in the event of injury resulting from research but that neither financial compensation nor free medical treatment is provided. I also understand that I am not waiving any rights that I may have against the University for injury resulting from negligence of the University or investigators.

If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below. A signature below means that I have freely agreed to participate in this study.

Title of Project: Ankle Kinetics in the Frontal & Sagittal Plane during Landing Tasks in Participants with Chronic Ankle Instability & Uninjured Controls.

Principal Investigator: Alison Bauer, PO Box 8082, Ph. 531-1439; abauer1@georgiasouthern.edu

Other Investigators: Caren Walls, Po Box 8082, Ph. 681-5686; caren_m_walls@georgiasouthern.edu

Julie Sandy, PO Box 8082, Ph. 871-1920; julesiu033@yahoo.com

Faculty Advisor: Dr. Bryan Riemann, PO Box 8076, 912-681-6268,
briemann@georgiasouthern.edu

Participant's Signature Date

Witness Date

INVESTIGATOR'S CERTIFICATION

I certify that the nature and purpose, the potential benefits, and possible risks associated with participation in this research study have been explained to the above individual and that any questions about this information have been answered.

Investigator's Signature Date

APPENDIX D

The Biomechanics Laboratory at Georgia Southern University

MEDICAL HISTORY FOR RESEARCH
Bauer Thesis Study

Today's Date: _____/_____/_____ Study Code/Participant Number _______

Personal Information

Age:_____ Date of Birth: _____/_____/_____ Sex:______ Dominant Arm: L R

Dominant Leg: L R Shoe size:_____________

Emergency Information

Do you have medical alert identification? _________ YES _______NO
If YES, where is it located? ____

Current Medications (include ALL medications)

Name of Drug	Dosage; Times/day	Why are you on this drug?

Hospitalizations

Please list the last three (3) times you have been ill (sick) enough to see a physician, been hospitalized or had surgery.

When?	What was done (surgery, etc.)?	Why was this done?

Family History

Have any members of your immediate family had, or currently have, any of the following?

	Age of onset	Heart Disease	Stroke	Sudden Diabetes	Pulmonary Sudden Death	Pulmonary Disease
Mother	______	______	______	______	______	______
Father	______	______	______	______	______	______
Sisters	______	______	______	______	______	______
Brothers	______	______	______	______	______	______
Aunts/Uncles	______	______	______	______	______	______
Grandparents	______	______	______	______	______	______
Don't know	______	______	______	______	______	______

Personal Medical History

Do you have any known allergies? ______ YES ______NO If YES, please explain:____

Do you use tobacco products? ______YES ______NO If YES, please describe product used (cigarettes, pipe, dip, etc.), how often per day (packs, bowls, etc.) and how long you have been a tobacco user (years):____

____

What is your cholesterol level? ____________ mg/dl ____________don't know

What is your *resting* blood pressure? ______________ mm Hg ___________ don't know

Please check the following disease conditions that you **had** or currently **have**:

____ High blood pressure
____ Aneurysm
____ Abnormal chest X-ray
____ High blood cholesterol
____ Anemia
____ Asthma
____ High blood triglycerides
____ Diabetes
____ Emphysema
____ Angina pectoris
____ Jaundice
____ Bronchitis
____ Heart attack
____ Hepatitis
____ Thyroid problems
____ Heart surgery (catheter, bypass)
____ Infectious mononucleosis
____ Hernia

____ Heart failure ____ Phlebitis ____ Cancer

____ Heart murmur ____ Gout ____ Epilepsy/seizures

____ Stroke/transient ischemia attacks ____ Kidney stones ____ Prostate problem

____ Rheumatic fever ____ Urinary tract infections ____ Osteoporosis

____ Arteriosclerosis ____ Emotional disorder (depression, etc.)____ Eating disorder

Please provide dates and explanation to any of the above which you checked:

____

____

Have you experienced, or do you currently experience any of the following on a *recurring* basis?

	At rest: YES	NO	**During exertion:** YES	NO
Shortness of breath	____	____	____	____
Dizziness, lightheadedness, fainting	____	____	____	____
Daily coughing	____	____	____	____
Discomfort in the chest, jaw, neck or arms	____	____	____	____
(pressure, pain, heaviness, burning, numbness)	____	____	____	____
Skipped heart beats or palpitations	____	____	____	____
Rapid heart rate	____	____	____	____
Joint soreness	____	____	____	____
Joint swelling	____	____	____	____
Slurring or loss of speech	____	____	____	____
Unusually nervous or anxious	____	____	____	____
Sudden numbness or tingling	____	____	____	____
Loss of feeling in an extremity	____	____	____	____
Blurring of vision	____	____	____	____

If YES to any of the above, please explain:

____

____

____

____

Orthopedic/Musculoskeletal Injuries

Please check the following disease or conditions which you had or currently have:

____ Stiff or painful muscles	____ Muscle weakness	____ Head injury
____ Swollen joints	____ Amputation	____ Shoulder injury
____ Painful feet	____ Fractures or dislocations	____ Ankle injury
____ Severe muscle strain	____ Tennis elbow	____ Whiplash or neck injury
____ Limited range of motion in any joint	____ Torn ligaments	
	____ Pinched nerve	____ Slipped disc
____ Bursitis	____ "Trick" knee/knee injury	____ curvature of spine

Do any of the above limit your ability to exercise? _____ YES _____NO If YES to any of the above, please explain:

____

____

Previous Ankle Injury History

1. Do you often experience feelings of "giving way" in your ankles during walking or other functional type activities? Y N

2. Have you experienced 2 or more moderate sprains to one ankle no more than 12 mos. ago but greater than 4 weeks? Y N If yes, what were the dates?_________________

3. Do you experience any of the following during activity?

Pain Swelling Stiffness Tenderness Giving way Weakness

4. Have you ever been diagnosed with any vestibular (ear) or neurological conditions? Y N
If yes, please explain.

5. Do you currently have any symptoms at this time? Y N If yes, please explain.

APPENDIX E

The Biomechanics Laboratory at Georgia Southern University

ACTIVITY LEVEL QUESTIONAIRE
Bauer Thesis Study

Today's Date: _____/_____/_____ Study Code/Participant Number _______

Circle the number that corresponds to your current physical activity level:

0 – Sick leave or Disability

1 – Sedentary work, minimal walking

2 – Light labor

3 – Light to moderate labor

4 – Moderate to heavy labor, recreational bicycling or light jogging

5 – Heavy labor, competitive bicycling, moderate jogging (2 times a week)

6 – Recreational tennis, basketball, moderate jogging (5 times a week)

7 – Competitive sports: tennis, track (running), basketball, baseball OR Recreational: soccer, hockey

8 – Competitive sports: track (jumping)

9 – Competitive sports: soccer, football, wrestling, gymnastics

10 – Elite level: soccer, football, basketball, running

How many days per week do you participate at this activity level? _________________

How many minutes per session?____

What specific activity(s) do you usually take part in?_____________________________

____

APPENDIX F

Ankle Score Scale (adapted from Kaikkonen et al.[19])

I	Subjective Assessment of the injured ankle	Points
	No symptoms of any kind Mild symptoms Moderate symptoms Severe symptoms	15 10 5 0
II	Can you walk normally?	
	Yes No	15 0
III	Can you run normally?	
	Yes No	10 0
IV	Climbing down stairs?	
	Under 10 seconds 10-11 seconds Over 11 seconds	10 5 0
V	Rising on heels with injured leg	
	Over 40 times 30-39 times Under 30 times	10 5 0
VI	Rising on toes with injured leg	
	Over 40 times 30-39 times Under 30 times	10 5 0
VII	Single-limbed stance with injured leg	
	Over 55 seconds 50-55 seconds Under 50 seconds	10 5 0
VIII	Laxity of the ankle joint (Anterior Drawer Test)	
	Stable (</= 5 mm) Moderate instability (6-10 mm) Severe instability (>10 mm)	10 5 0
IX	Dorsiflexion Range of Motion, injured leg	
	>/=10 degrees 5-9 degrees <5 degrees	10 5 0
	Total:	
	Excellent= 85-100 Good = 70-80 Fair = 55-65 Poor </= 50	

I. Subjective Assessment: Participants were asked to select from a list of symptoms, those that are experienced during activity. The symptoms included pain, swelling, stiffness, tenderness, or giving way. The subjective assessment was classified as mild if only one of these symptoms is present; Moderate if 2-3 of these symptoms are present; Severe if 4 or more of these symptoms are present

II. Walk Normally: Participants were asked about his/her ability to walk normally without difficulty or giving way at the ankle.

III. Run Normally: Participants were asked about their ability to run normally without difficulty or experiencing giving way at the ankle.

IV. Stairs: Participants stood at the top of a flight of 22 stairs (height= 18 cm, depth 22 cm). They were instructed to walk down the stairs one step at a time as they normally would walk down stairs. Time to complete the task was measured with a standard stopwatch.

V. Rising on Heels: Participants were instructed to stand on the involved limb, with the opposite leg flexed about 90° in a relaxed position. The hands were held behind the back. To the beat of a metronome set at 60 bpm, participants were instructed to bring the forefoot off the ground, rising on the heel. Participants performed this task until fatigue, and the number of repetitions was counted by the principal investigator.

VI. Rising on Toes: Participants were instructed to stand on the involved limb, with the opposite leg flexed about 90° in a relaxed position. The hands were held behind the back. To the beat of a metronome set at 60 bpm, participants were instructed to rise up on toes. Participants performed this task until fatigue, and the number of repetitions was counted by the principal investigator.

VII. Balance: Participants were instructed to balance on the involved limb on a platform (width= 10cm) for as long as possible. The participant kept his/her hands behind his/her back and was allowed to have the eyes open. Participants were cut-off at an upper limit of 56 seconds.

VIII. Laxity An anterior drawer test was performed bilaterally to determine the level of mechanical instability in the involved ankle. The anterior drawer test is used to assess the integrity of the anterior talofibular ligament, the most commonly injured ligament sustained during a lateral ankle sprain.

IX. Dorsiflexion ROM. Standard goniometry measurements were taken for dorsiflexion of the test limb. Subjects sat on a table with the hips, knees, and ankle flexed at 90°. Participants actively dorsiflexed foot, and the measurement was taken.

APPENDIX G

ALISON BAUER

THESIS DATA COLLECTION
DATA SHEET

DATE________________ CAI HEALTHY

PARTICIPANT #____________________ MATCHED PARTICIPANT #_____

HEIGHT___________________________ MASS______________________________

DOMINANT LEG R L

PHYSICAL ACTIVITY
TYPE____

____

TEGNER/LYSHOLM SCORE___________ ANKLE ACTIVITY SCORE______

CALCULATED HOP DISTANCES:

VERTICAL_____________________________
(20% of height)

CROSS-0VER__________________________Horizontal/Vertical__________________
(45% of height; vertical and horizontal components = 45% of height divided by √2)

PREVIOUS INJURY HX:

1. When you initially sprained your ankle, was it moderate to severe and required medical attention? Y N
2. Have you experienced 2 moderate ankle sprains to one ankle no more than 12 months ago, but greater than 4 weeks ago? Y N
3. Did you experience weakness/pain from this sprain? Y N
4. Do you have any sx right now? Y N

CHRONIC ANKLE INSTABILITY EVALUATION

1. SUBJECTIVE
    - No symptoms 15
    - Mild Symptoms 10
    - Moderate Symptoms 5
    - Severe Symptoms 0
2. WALK NORMALLY?
    - Yes 15
    - No 0
3. RUN NORMALLY?
    - Yes 10
    - No 0
4. CLIMBING DOWN STAIRS
    - Under 18 seconds 10
    - 18-20 seconds 5
    - Over 20 seconds 0
5. RISING ON HEELS
    - Over 40 times 10
    - 30-39 times 5
    - Under 30 times 0
6. RISING ON TOES
    - Over 40 times 10
    - 30-39 times 5
    - Under 30 times 0
7. SINGLE-LIMB STANCE
    - Over 55 seconds 10
    - 50-55 seconds 5
    - Under 50 seconds 0
8. LAXITY OF ANKLE JOINT
    - Stable (≤5 mm) 10
    - Moderate instability (6-10mm) 5
    - Severe instability (>10 mm) 0
9. DORSIFLEXION ROM
    - ≥10° 10
    - 5°-9° 5
    - <5° 0

TOTAL:______________